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R. HOLLIDAY

CACAO

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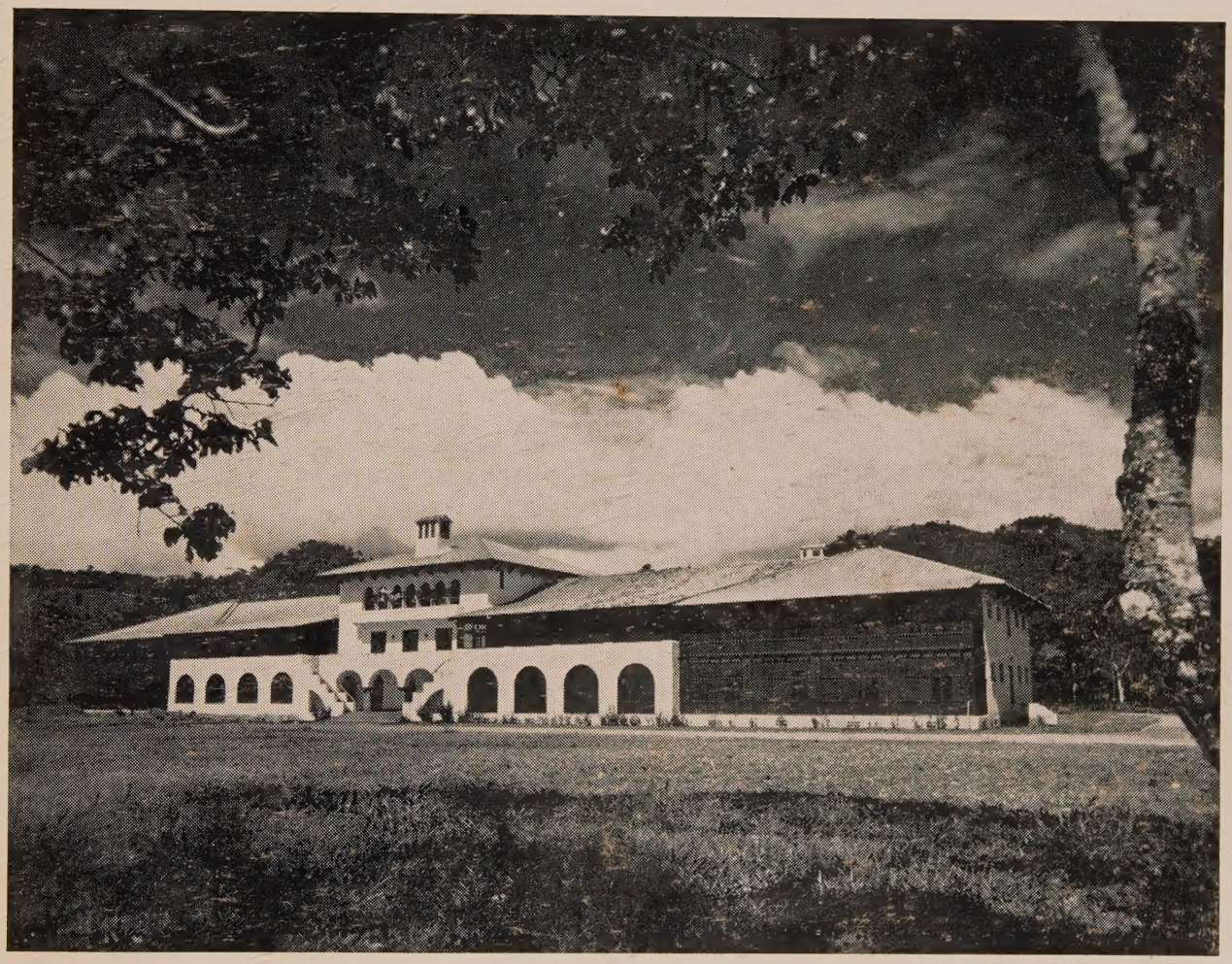

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V REUNION DEL COMITE TECNICO INTERAMERICANO DEL CACAO, JULIO 4-10, 1954

I Volumen

TRABAJOS PRESENTADOS

Instituto Interamericano de Ciencias Agrícolas
Turrialba, Costa Rica

BREVE EXPLICACION

Con el fin de facilitar la labor de secretaría, se dispuso incluir en este I Volumen sólo aquellos trabajos que fueron presentados dentro del plazo preestablecido. Los que han llegado posteriormente aparecerán en la segunda parte del II Volumen, que está dedicado a las recomendaciones.

Algunos de los trabajos presentados tienen fotografías. La limitación del tiempo impidió incluír las reproducciones. Sin embargo, las personas que tengan interés en estas fotografías pueden solicitar copias fotostáticas, escribiendo al Centro Interamericano del Cacao, Instituto Interamericano de Ciencias Agrícolas, Turrialba, Costa Rica.

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A SURVEY OF THE FERTILITY STATUS OF THE CACAO SOILS OF COSTA RICA, AS DETERMINED BY SOIL AND LEAF ANALYSES, AND A PRELIMINARY STUDY OF THE RELATION OF DEPTH OF ROOTING OF COCOA TREES TO SOIL DRAINAGE *

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During the first half of 1953 some 350 soil samples and 250 leaf samples were taken in the cacao and coffee areas of Costa Rica. The sampling locations were chosen with the help of the technical staff of the Costa Rica Ministry of Agriculture, the United Fruit Company S.T.I.C.A. and the Inter-American Institute of Agricultural Sciences. Cooperators in these organizations generously gave their time and made transportation facilities available for the purpose of obtaining the samples. Some of the funds for doing the work were provided by the American Cacao Research Institute. The chemical analyses were made in the laboratories of the Pomology Department of Cornell University, Ithaca, New York, U. S. A.

As a result of this cooperative effort, it was possible to obtain soil and leaf samples in representative cacao and coffee plantings in all of the major soil and climatic variations of Costa Rica. These included the east and west coast cacao areas, and the main coffee areas centered on the Meseta Central and at Turrialba. In the coffee areas samples were taken from farms whose soils ranged from old latesols to those derived from recent volcanic ash. In some cases, samples were taken from areas in farms where tentative diagnosis of zinc, boron or magnesium deficiency had been made. At the same time, a study was made of the effect of age of leaf and time of sampling on the concentration of eight nutrient elements in cacao and coffee leaves.

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* This report summarizes some of the information in a Thesis written by Fenton B. Sands in partial fulfillment of the requirement for the degree of Ph.D., submitted to the Cornell University Graduate School in June, 1954. The data discussed herein will be published at a later date in connection with a more comprehensive paper under the senior authorship of Mr. Sands

The samples and observations at each location were taken in a standardized way. A composite of four borings, at 0-12 inch depth and 12-24 inch depth, was taken at each location. Ten leaves from each of ten coffee trees and from each of four cacao trees constituted a leaf sample. The fourth leaf from the terminal was the leaf sampled. The leaf samples were washed and dried at relatively low temperature, and the soil samples were dried and sieved. At Cornell University, the leaf samples were analyzed for N, P, K, Ca, Mg, Mn, B and Zn, and the soil samples for moisture equivalent, base exchange capacity, total N, pH, exchangeable K, Ca, Mg, Mn, and easily soluble B and Zn.

RESULTS

A brief summary of some of the results pertinent to this conference is made below.

Soil Samples

Table 1 gives a comparison of the average analyses and the ranges of these values for the soil samples from the cocoa and coffee areas.

The Moisture Equivalent, as percent of dry weight, and the Base Exchange Capacity as milli-equivalents per 100 grams of soil serve as measures of the capacities of these soils for available water and for nutrient cations. The Moisture Equivalents of both surface and subsoil samples of the cocoa and coffee areas ranged from values indicating silty clay loam texture to values indicating sandy loam texture with silt loams texture as the most common situation. The ranges and the means for the two areas did not differ markedly. Base Exchange Capacity varied more than Moisture Equivalent, showing wider ranges for each region, greater average differences between regions, and greater average differences between surface and subsoil samples. The Base Exchange Capacities of the surface soils averaged considerably higher than those for subsoils in both regions. Although the average Exchange Capacities for the soil samples in the two regions did not differ markedly, the ranges for the coffee soils were much greater and the minimum levels much lower than those for the cocoa soils. In general, the Exchange Capacities of the coastal cocoa soils were a little

higher and varied less than was the case for the coffee soils.

Total Nitrogen, as percent of dry weight, is a measure of the amount of organic matter in the soil samples. As would be expected, the average Total Nitrogen content of the surface soils of both regions was higher than the average Total Nitrogen content for their subsoils. This undoubtedly accounts for the higher Base Exchange Capacities of the surface soils. It is interesting to see that the Total Nitrogen of the coastal cocoa soils averaged much lower than that for the coffee soil samples, in spite of the fact that the cocoa soils are all recent alluvium. Since the Base Exchange Capacities of the coastal soil samples are a little higher than those from the interior, in spite of their lower Total Nitrogen content, it seems possible that they are higher in inorganic colloids.

Under the humid conditions prevailing in this climate, Total Bases (Ca + Mg + K + Mn in m.e. per 100 g. soil), Percent Base Saturation (Total Bases ÷ Exchange Capacity) and pH all reflect the degree to which the Base Exchange Capacity of the soil is filled with the major nutrient cations. Table 1 shows that there was rather little difference in the averages of these measurements for the surface coils as compared to the subsoils. It also reveals that the cocoa soils averaged much higher in Total Bases, Percent Saturation and pH, and that their variation in Bases Saturation was less, than was the case for the coffee soil samples. It should be emphasized, however, that some of the samples from the coffee area were among the highest in Percent Base Saturation.

Examination of the data for Exchangeable Ca, K, and Mg in Table 1 reveals that the surface and subsoil samples for each region were relatively similar but that there were very great differences between the two regions. The averages for Exchangeable Ca and Exchangeable Mg were more than twice as high in the coastal soil samples as in those from the interior and their ranges were much less. On the other hand Exchangeable K averaged considerably less in both the surface and subsoil samples of the cocoa regions than in those of the coffee regions.

5RTIC/Doc.3
Suelos/1

Exchangeable Mn, soluble Zn and soluble B were a little higher in the surface than in the subsoil samples in both regions. The averages for Exchangeable Mn in the two areas were quite similar, but it may be significant that a very low minimum level was recorded for the coffee soil samples. Soluble Zinc averaged lower in the cocoa samples, although the minimum levels encountered were the same in both areas. Soluble Boron averaged a little lower in the cocoa samples but slightly lower minimum levels were found in the coffee samples.

By way of summary, it may be said that in general the cocoa soil samples appeared to be relatively high in Exchange Capacity, in Saturation with Bases, and in Souble Zinc and Boron. While the minimum levels of the various nutrient elements may have been low enough to permit occasional deficiency of one or another of these elements, under conditions of unbalance or physiological stress, these data do not suggest the likelihood of widespread deficiencies of the nutrients determined. Neither do they suggest abnormally high levels or unbalances. In contrast, low Base Saturation of a considerable proportion of the samples from the coffee regions is indicated by the data, and along with it troubles from both simple deficiencies and unbalances of several of these elements.

Table 2 deals with these same analyses of the cocoa soil samples, arranged by averages for the areas within which they were collected. For the 46 sampling locations considered in Table 1, five areas have been designated --one for the west coast and four for the east coast, the latter extending along the Northern Railroad from Siquirres at the northwestern extreme, to the Estrella river at the southeastern extreme. Seven additional sampling locations in this interior are also considered--three from the Guapiles area and four from the Turrialba area. These samples were taken in present or prospective small cocoa plantings, all but two of which are experimental.

The small numbers of sampling locations in each of the areas make it hazardous to consider seriously any but the largest deviations of a particular average from the remainder. With this in mind, it is interesting that the averages for the six sampling locations

from the Damas area of the west coast, with a prolonged dry season and average annual rainfall considerably less than one hundred inches, should be so similar to those for the forty east coast sampling locations, where there is no pronounced dry season and rainfall averages well above one hundred inches. If any of these averages differ significantly, those for Magnesium (higher on the west coast) and Potassium (lower on the west coast) may be of particular interest. It is clear that the "Interior" sampling locations are vastly different from the coastal ones and approximate the averages for the coffee samples given in Table 1. Among the East Coast sampling areas, the Siquirres averages are of interest in that they suggest soil predominantly lower in Water Holding and Exchange Capacities. This may be due to the fact that this area is flooded more frequently than the others and that during the flooding of the Reventazón and Pacuare Rivers turbulence of the flood waters in this region which lies between them is considerable. In contrast, the averages for the Estrella area indicate heavier soil and greater fertility than the east coast averages.

Leaf Samples

Table 3 summarizes the data on chemical composition of leaves sampled from the four cocoa trees which constituted the sampling unit at each location, and under which the soil samples were taken. As stated before, ten leaves were composited from each of these trees, the fourth leaf from the terminal on vegetative shoots being the sampling material. The leaves were washed in tap water and dried at about 70° C as soon as possible after sampling.

Unfortunately it was necessary to collect the samples over a period of several months (From February until June) and during this period two flushes of growth occurred. Variations in exposure to sunlight, which affected leaf age directly and indirectly were also encountered. This meant that the phenological age of the fourth leaf from the terminal varied considerably from sample to sample. In general, the leaves from the Damas area and the "Interior" locations were older than those from the other areas.

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Suelos/1

In a study of the influence of leaf development and age on the chemical composition of the cocoa leaf, made during this same period, as well as in such studies with a number of other species, it has been demonstrated conclusively that with increasing age nitrogen, potassium and phosphorus decreased in concentration, calcium increased, and magnesium did not vary greatly. In the leaf sampling studies with cocoa and coffee, the trends for Manganese and Boron concentrations were less consistent than Macronutrients, the former appearing to increase and the latter to decrease with increasing leaf age. Zinc concentration decreased markedly with leaf age. Thus the variations in leaf age make evaluation of the data in Table 3 difficult.

Another consideration that increases the difficulty of interpretation of Table 3, is the lack of leaf analyses in association with response data for cocoa trees, to use as a basis for estimation of deficiency, sufficiency, and luxury consumption levels. Thus far, we have only data from Trinidad to indicate that under some conditions a leaf potassium level below 1.85 percent of dry weight may be associated with potassium deficiency, and the results of a recent experiment at Turrialba to indicate that there were responses of young cocoa seedlings to Magnesium and Calcium when leaf Mg was below o.2 percent and leaf Calcium was below 0.4 percent of dry weight.

Suffice it to say, then, that the leaf analyses in Table 3 can only be used as general background information on the concentrations of these elements that were found under the varying conditions of leaf age and soil in this study. It can be seen that the ranges of all these elements, as percent or parts per million of dry leaf tissue, were great, and that rather low levels of all of them were found in one or more sampling location. On the other hand, the averages for all of them were well above minimal levels of sufficiency established for other woody species, and it seems likely that most of these trees were not limited in productivity by lack of any of the nutrients assayed.

Preliminary Studies of the Depth of Rooting of Cocoa Trees in Relation to Soil Drainage

During the course of the above survey it was not

uncommon to find areas in cocoa plantings within which the tree stand was poor or the trees were lacking in vigor and appeared to be poorly rooted. When soil samples were taken to a depth of two feet there was occasionally evidence of mottling or grayness in the subsoil; this was most evident in the sampling locations of the Estrella and La Lola areas. In other cases, the poor stand or appearance could be attributed to serious and repeated flooding; this was most serious in the sampling locations of the Siquirres area. In still other cases, there were no apparent relationships with surface or subsoil drainage conditions.

In order to study the possible relationships between tree appearance, depth of rooting and soil drainage, eighteen excavations were made under mature cocoa trees at representative locations on the La Lola farm of the Inter-American Institute of Agricultural Sciences. This farm of 80 hectares is situated between Siquirres and Zent on the eastern coastal plain of Costa Rica. The sites were chosen to represent different elevations and different surface drainage situations. Twelve of the sites were under the branches of trees of low vigor, and six were under the branches of vigorous trees.

Under each tree and excavation was made tangent to a circle three feet from the trunk; the dimensions of the excavation were six feet long, two feet wide and four feet deep or as deep as rooting occurred. The face of the ditch closest to the tree was then marked by the use of string pegged to the soil at one foot intervals horizontally and vertically, a qualitative description of the soil profile was made, and a sample of each layer was taken for physical and chemical analyses. Then, the roots appearing on the face of the ditch were located on a profile map, according to five categories of cross sectional dimensions.

Table 4 summarizes the data on the average numbers of roots of different dimensions per one foot depth that were found for the two categories of trees. Two conclusions seem justified from this table: (1) the great majority of roots were found in the top two feet of soil regardless of the tree vigor; and (2) the more vigorous trees rooted more deeply. The qualitative observations made on the faces of these ditches indicated

that there were two soil conditions which were associated with shallow rooting: (1) poor internal drainage, as evidenced by grayness and/or gray and rusty mottling of the subsoil above two feet, and sometimes in depressional topography accompanied by seepage of water into the excavation; (2) compacted gravelly clay or boulders above two feet which appeared to impede root penetration mechanically if not as a result of poor aeration.

While this limited study does not permit generalization, it does point to the possibility that subsoil conditions limiting the depth and ramification rooting may be as important as or more important than the chemical availability of plant nutrients in these coastal soils which appear to be inherently rather fertile. If this is true, it may well be that subsoil conditions affecting depth of rooting are a particularly important limiting factor in the west coast cocoa area because of the long period of dry weather which the trees must endure annually.

GENERAL OBSERVATIONS AND CONCLUSIONS

It seems clear that this reconnaissance survey must be regarded as a small beginning in the attack of a group of complex, interrelated problems in the diagnosis of the nutritional requirements and status of cocoa trees.

The data on the chemical analyses of the soil furnish a quantitative basis for comparison of the fertility status of different existing or potential cocoa areas. But much more experimental evidence and many more field observations must be made on the growth, productivity and symptomatology of the cocoa tree under different conditions of soil fertility before it will be possible to use soil analysis as a criterion of fertilizer needs of the trees in a particular area. A bank of information on analyses of soil samples, taken and processed in standard ways, from situations of known productivity, or showing particular problems in the different cocoa areas of the Caribbean area or perhaps the world, would undoubtedly be of great value to cocoa technologists concerned with the agronomic problems of the crop.

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The same things may be said about the data on leaf analyses in this study. It presents some preliminary information on ranges and averages of several nutrients, but additional work on sampling and processing procedure must be done before such analyses may be widely used in diagnostic work. This should be accompanied by experimental studies of the concentrations of the various nutrient elements on cocoa leaves, in relation to appearance of deficiency symptoms or to growth responses. And with this background a bank of information on analyses of cocoa leaf samples taken and processed in standard ways from the various cocoa regions of the Caribbean area or the world would complement such data on soil analysis in a very valuable way.

Soil and leaf analyses can only be valuable in diagnosis of fertilizer problems if they are complemented by knowledge with respect to other possible limiting factors. The preliminary study of the association of depth of rooting and tree vigor illustrates this point. If poor soil drainage limits the ability of cocoa trees to root satisfactorily, this condition may have to be cared for before economic fertilizer responses can be expected. Likewise, the complex effects of leaf diseases and light exposure on productivity of cocoa trees may mean that one or the other of these conditions may preclude responses to fertilizers. This being the case, any use of soil and leaf analyses in the diagnosis of fertilizer problems of cocoa has to be accompanied by knowledge about the physical condition of the soil, the disease and light relations of the trees and any other variables in the environment of the trees that might modify their responses to essential nutrients.

TABLE 1. Comparison of the Analyses of Soil Samples from 46 locations on Coastal Cocoa Farms and From 71 Locations on Interior Coffee Farms in Costa Rica, 1953.

	Cocoa soils (coastal)						Coffee soils (interior)					
	Surface (0-12")			Subsoil (12-24")			Surface (0-12")			Subsoil (12-24")		
Number Sampling Locations		46			45			71			69	
	av.	high	low	av.	high	low	av.	high	low	av.	high	low
Moisture Equivalent (% d.w.)	34.9	46.5	19.5	33.1	42.0	18.8	36.2	56.4	15.1	33.5	52.0	15.4
Total Nitrogen (%d. w.)	.168	.276	.050	.075	.214	.38	.355	1.144	.125	.213	.695	.057
Base Exchange Capacity (m.e./100 g)	36.8	47.0	26.3	35.4	47.6	19.4	35.5	63.8	12.3	32.8	64.8	6.2
Total Bases (m.e./100 g)	30.7	40.5	16.8	30.6	38.7	14.5	13.1	61.4	0.6	11.7	58.0	0.3
Percent Base Saturation	83.2	98.8	63.8	84.4	99.2	69.9	36.0	97.4	2.1	34.2	90.1	1.3
pH	5.8	7.4	5.1	5.8	7.5	5.3	5.3	6.2	4.1	5.3	6.5	4.1
Exchangeable Ca (m.e./100 g)	24.4	32.2	12.6	23.5	29.6	11.8	9.9	45.0	0.2	8.6	40.5	0.1
Exchangeable K (m.e./100 g)	0.50	1.21	0.13	0.35	1.19	0.12	0.74	2.06	0.12	0.63	3.54	0.07
Exchangeable Mg (m.e./100 g)	5.72	10.20	1.33	6.71	14.79	0.10	2.38	15.40	0.03	2.48	16.52	0.03
Exchangeable Mn (m.e./100 g)	.064	.173	.010	.052	.150	.013	.059	.163	.001	.050	.168	.001
Soluble Zn* ppm	2.7	9.9	0.4	1.5	4.0	0.4	4.5	21.2	0.2	3.2	18.0	0.4
Soluble B** ppm	0.91	1.95	0.57	0.88	1.54	0.48	1.05	2.37	0.43	0.95	2.23	0.39

* Soluble in ammonium acetate pH7
** Soluble in boiling water

TABLE 3. Comparison of the Analyses of Composite Samples of Leaves from the Mature Cocoa Trees Under Which the Soil Samples of Tables 1 and 2 Were Taken, Costa Rica, 1953.

	Number		N	K	Ca	Mg	P	Mn	Zn	B
			percent of dry weight					parts per million		
All Samples	50	av.	2.07	2.07	0.93	0.41	0.20	77	49	43
		high	2.66	2.78	2.10	0.60	0.25	230	83	66
		low	1.34	0.90	0.34	0.17	0.12	17	20	19
West Coast										
Damas	6	av.	1.60	1.73	1.22	0.53	0.19	59	67	43
		high	1.73	1.81	1.57	0.60	0.21	91	76	53
		low	1.34	1.56	0.94	0.45	0.17	36	54	36
East Coast										
Siquirres	8	av.	2.22	2.46	0.63	0.35	0.21	44	35	50
		high	2.42	2.75	0.72	0.38	0.23	59	48	56
		low	2.07	2.18	0.54	0.28	0.17	29	24	41
La Lola	6	av.	2.18	2.47	0.74	0.40	0.20	83	52	34
		high	2.58	2.78	0.84	0.55	0.25	120	60	52
		low	1.99	2.01	0.69	0.29	0.19	67	41	22
Zent	14	av.	2.16	1.97	0.90	0.37	0.21	70	55	43
		high	2.54	2.57	1.57	0.47	0.24	167	83	66
		low	2.05	1.42	0.34	0.17	0.15	32	40	20
Estrella	12	av.	2.13	2.13	0.89	0.41	0.19	74	57	40
		high	2.66	2.40	0.98	0.54	0.23	195	79	56
		low	1.57	1.82	0.68	0.33	0.17	17	41	19
Interior	4	av.	1.84	1.41	1.66	0.50	0.14	195	28	47
		high	1.94	2.02	2.10	0.57	0.15	230	33	57
		low	1.73	0.90	1.13	0.42	0.12	150	20	38

TABLE 4. The Relation of Depth of Rooting to Condition of Cocoa Trees as Indicated by the Number of Roots per 1 Foot Depth in Ditches 3 Feet From the Trunk and 6 Feet Long, La Lola Farm, 1954.

	Vigorous Trees (av. of 6)						Weak Trees (av. of 12)				
	Cross sectional diameter of roots (mm)						Cross sectional diameter of roots (mm)				
	0-2	3-5	6-10	11-20	20		0-2	3-5	6-10	11-20	20
	av. no. roots per 1 foot depth						av. no. roots per 1 foot depth				
Depth 0-12"	107.0	20.8	6.8	0.9	01.8	Depth 0-12"	122.0	20.5	6.7	3.1	0.8
12-24"	59.5	11.8	1.5	0.2	0.5	12-24"	32.6	6.6	2.4	0.5	0.3
24-36"	15.0	6.6	0.9	0.2	0.0	24-36"	3.7	1.7	0.3	0.0	0.0
36-48"	1.2	1.7	0.0	0.0	0.0	36-48"	0.0	0.1	0.0	0.0	0.0

24 junio 1981
CACAO-1

5RTIC/Doc.4
Suelos/2

A RESPONSE OF SEEDLING CACAO TREES, UNDER NURSERY CONDITIONS, TO MAGNESIUM AND CALCIUM

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Turrialba, Costa Rica

In connection with clonal comparisons and disease control experiments, some beds in a nursery at the Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica, were planted with seed of United Fruit Co. cacao clon #613 at several different times during 1952. All of the plantings were kept under partial shade provided either by frames covered with a native wild cane (caña brava) and banana leaves or by trees; routine watering and rain provided ample soil moisture. The soil used for the seedbeds and pots was a dark brown silty clay loam, high in organic matter, but rather low in pH, and very low in base saturation (see table 2), which was said not to have received commercial fertilization in the years previous to use in the nursery.

Germination and initial growth of the seedlings were often satisfactory, but after two to three months of growth the older leaves of many of the plants began to show an interveinal chlorosis which was followed by necrosis of the chlorotic areas. The various stages of development of the symptom are illustrated in figure 1. The interveinal chlorosis was evident on the older leaves first and progressed toward the younger leaves of affected shoots. Chlorosis usually preceded interveinal necrosis, but sometimes the development of necrotic lesions was sudden and may have occurred without much loss of chlorophyll in the affected zones. The necrotic lesions grow in area with time and frequently joined each other and progressed to the leaf margins. There was premature abscission of severely affected leaves. The terminal leaves of plants whose basal leaves showed this symptom often appeared normal, although on the most severely affected ones the tip leaves seemed generally chlorotic as well as small.

RESULTS

Leaf spray applications:--Since this symptom complex resembled that of magnesium deficiency in other crops, in February 1953 leaf sprays of epsom salts at 2%, in comparison with solutions of urea, potassium phosphate, manganese, zinc and iron sulfates were applied at weekly intervals to individual basal leaves of some plants in the bamboo pots showing the chlorosis phase of the symptoms. There was no recovery as a result of any of these treatments even after five applications. Since the plants were not in active growth, however, it was not possible to study the effects of these nutrient sprays on new growth.

Experiment 1:--On February 19, 1953 an experiment involving 4 replications of 4 soil treatments was started in one of the beds in which the interveinal chlorosis symptoms had caused serious loss of effective leaf surface on cacao plants in a previous experiment. Table 1 shows the materials used and the rates of application. Each plot covered approximately 10 square feet in area. The soil amendments were raked to a depth of 3 inches into the freshly cultivated soil, and in each plot were planted 30 seeds from freshly harvested pods of #613 clon U.F.

The germinating seedlings appeared above ground in about two weeks, and by April 15 it was evident that the early growth of the plants in treatments 1 and 2 which received no calcium was inferior to that in treatments 3 and 4 which had calcium amendments. Shortly after that, the interveinal chlorosis symptom appeared on basal leaves of some plants in treatment 1, and the chlorotic areas soon developed necrotic lesions. During the first six weeks of the experiment the trees in plots 3 and 4 continued to grow at a faster rate than these in the other two treatments, and no leaf symptoms appeared in treatment 3.

By mid-May, however, it was evident that the necrosis symptom was developing on some of the plants in treatment 4, and also that the plants of treatment 2, with three exceptions, were free of the necrosis symptom. At this time the general appearance of the plants in treatment 2 was better than the appearance of the untreated plants of treatment 1. When the experiment was

terminated on June 1, the four treatments were visually different. Treatment 1 had poor stand, small trees, and a great deal of interveinal leaf scorch and chlorosis. Treatment 2 had poor stand, small trees and very little leaf damage. Treatment 3 had good stand, large trees and no leaf scorch. Treatment 4 had reasonably good stand, large trees, but some interveinal leaf scorch and chlorosis. Table 2 summarizes the observations on the plants in experiment 1 at the end of the experimental period.

The leaves of the plants in each replicate of each treatment were dried at 60°C., ground in an intermediate Wiley mill and analyzed for K, Mg, Ca and P. From each of the plots a composite soil sample was taken by combining six borings to a depth of 4 inches. These samples were analyzed for pH, exchange capacity, and exchangeable Mg, Ca and K. The methods of analysis used were modifications of those proposed by Peech (5). The leaf ash solution and the solution of exchangeable bases were made up in 0.1 normal HNO_3. Potassium and calcium were determined in aliquots of this solution by use of the Perkin-Elmer flame photomoter. Magnesium was determined colorimetrically by the use of thiazole yellow. Manganese was determined by the periodate procedure and phosphorus by the molybdate procedure. The leaf and soil analyses data for experiment 1 are summarized in table 3.

Looking first at the leaf analyses from the check plots, it is evident that magnesium and calcium were low, potassium was high and phosphorus intermediate, in terms of the levels found in mature leaves of other species. There were marked increases in leaf magnesium due to the addition of epsom salts, but the application of potassium appeared to inhibit magnesium absorption to some extent. Calcium application was accompanied by increased calcium content of the foliage, although magnesium alone and potassium seemed to inhibit calcium absorption to some extent. Potassium was extremely high in all treatments, but the concentration was somewhat reduced by calcium and magnesium additions. Phosphorus did not vary significantly. Leaf manganese was rather high in all treatments and was materially decreased by the calcium amendments. The soil analyses data give evidence that the initial exchangeable magnesium and calcium levels of the soil were very low and

the initial potassium level was high. There was a clear unbalance of potassium in relation to the divalent cations. Addition of potassium phosphate tended to accentuate the unbalance, whereas addition of epsom salts and calcium hydroxide in combination tended to counteract it.

Following the harvesting of the plants in experiment 1, the beds were replanted to a second set of cacao seedlings without further soil amendments. These trees were allowed to grow until September 9, at which time final observations on growth and symptoms were made, and the plants were harvested for weighing and chemical analysis. Although rainfall was much heavier, the results of the second run were similar in every way to those reported in tables 2 and 3 and are therefore not presented here.

Experiment 2:--In order to obtain evidence on the effects of the calcium amendment alone and the potassium phosphate amendment alone on the growth and symptom development of cacao plants on this soil, a second experiment was set up. For this, we used two nursery beds adjacent to that of experiment 1 and in which the same trouble had occurred to a lesser extent. The same salts were used at the concentrations indicated in table 1, and the same four treatments were used along with two additional ones: $Ca(OH)_2$ and K_2HPO_4 by themselves. Thus there were six treatments, and each was replicated six times. The trees were allowed to grow until September 9, at which time final observations were made and the trees were removed for weighing and analysis. Soil samples were also taken as in experiment 1.

The results are summarized in table 4. They confirm the tentative conclusion derived from tables 2 and 3, that the calcium amendment was most important in fostering maximum stand and growth, but that the magnesium amendment was necessary to overcome the interveinal necrosis. There is also convincing evidence of the detrimental effect on stand, growth and magnesium absorption caused by the potassium amendment under these conditions of low base saturation and high exchangeable K.

DISCUSSION AND CONCLUSIONS

There seems to be no doubt that the interveinal chlorosis and necrosis observed in these nursery beds was due to magnesium deficiency occurring under conditions of very low calcium nutrition and rather high potassium supply. Although the symptoms are not the same as those described by Greenwood and Djokoto (4) for magnesium deficiency of cacao under sand culture conditions, they are very similar to the symptoms of magnesium deficiency in other species including the apple (2) and citrus (3). Also, the chemical analyses of leaves and soil give conclusive confirmation. In this particular instance, the specific reasons for the beneficial effects of calcium cannot be identified with certainty. In view of the extremely low Ca status of the soil, it seems likely that there was a direct nutritional effect that resulted in better stand and better growth. But this was accompanied by a decrease in manganese content of the foliage from Mn levels that could have been toxic. It was also accompanied by a decrease in the potassium content of the foliage, under conditions of such high potassium availability that potassium supplements were detrimental to stand and growth.

The base saturation of this soil was lower at pH levels close to 5.0 than might be expected from most of the published studies of the relationship. This was probably due to the fact that the ultimate pH of the inorganic soil colloidal material was relatively high. Ayres (1) has shown that it is possible for soil under high-rainfall conditions in Hawaii to be less than 5 per cent saturated with calcium, magnesium and potassium and yet approach pH 5.0. It is interesting that under the conditions studied by him as well as those of this study, potassium saturation was sometimes higher than calcium saturation. Ayres' samples came largely from sugar plantations in which potassium fertilization is very common, and their high replaceable potassium may have been partly due to that fact. So far as is known, no potassium supplements had been made in the past to the nursery soil in this study, but it is possible that it came from an area in which plant refuse had been burned.

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Table 1. Materials and amounts used in the four experimental treatments. Pounds per acre.

	Treatment			
	1	2	3	4
$MgSO_4.7H_2O$	0	500	500	500
$Ca(OH)_2$	0	0	2000	2000
K_2HPO_4	0	0	0	500

Table 2. Growth responses and symptom development of seedling cacao plants under different soil treatments in experiment 1. Average for 4 replications of each treatment.

	Treatment				L.S.D.[a] Odds 19:1
	Ck. 1	+Mg 2	+Ca+Mg 3	+Ca+Mg+K+P 4	
Average number of plants standing 6/1/53	11.3	14.3	20.8	16.8	5.7
Average per cent of full stand 6/1/53	37.5	47.5	69.1	58.3	
Average dry weight leaves per plant (g)	0.53	0.65	0.79	0.80	
Average dry weight of shoots (g)	0.69	0.83	1.04	0.97	
Average dry weight of roots (g)	0.70	0.82	0.83	1.08	
Average dry weight total plant (g.)	1.92	2.30	2.66	2.85	.37
Average number of leaves per plant	4.2	4.5	4.6	4.9	
Average per cent of plants affected with interveinal necrosis	71	5	0	15	10
Average number of leaves affected per plant	2.4	0.2	0	0.4	
Average severity rating (visual observation)	3	1	0	1	

[a] Least significant difference

Table 3. Chemical analysis of leaves and soil taken from the different cacao nursery plots of experiment 1. Averages for 4 replications of each treatment.

	Treatment				L.S.D.[a] Odds 19:1
	Ck. 1	+Mg 2	+Ca+Mg 3	+Ca+Mg+K+P 4	
Leaves					
Mg (% dry wt.)	0.16	0.30	0.32	0.20	0.09
Ca (% dry wt.)	0.40	0.26	0.74	0.59	0.10
K (% dry wt.)	2.64	2.35	2.42	2.87	0.33
P (% dry wt.)	0.19	0.20	0.19	0.20	N.S.
Mn (% dry wt.)	0.021	0.020	0.013	0.012	0.004
Soil					
pH	4.75	4.87	5.04	5.21	0.10
Exchange capacity (m.e./100 g. soil)	35.5	37.5	38.8	38.1	N.S.
Exchangeable Mg (m.e./100 g. soil)	0.05	0.20	0.17	0.22	0.04
Exchangeable Ca (m.e./100 g. soil)	0.47	0.56	1.84	2.12	0.35
Exchangeable K (m.e./100 g. soil)	0.59	0.55	0.56	1.29	0.05
Per cent saturation with Mg, Ca, K	3.04	3.47	6.68	9.55	1.32

[a]Least significant difference.

Table 4. Growth symptom development and chemical analysis of seedling cacao plants under different soil treatments in experiment 2. Averages for 6 replications of each treatment unless otherwise noted.

	Treatment						L.S.D.[a] Odds 19:1
	Ck. 1	+Ca 2	+Mg 3	+K+P 4	+Ca+Mg 5	+Ca+Mg+K+P 6	
Average number of plants standing 9/9/53	17	22	18	10	20	18	4
Average per cent of full stand	57	72	61	33	67	62	
Average dry weight of total plant (g.)	1.23	1.51	1.34	0.97	1.76	1.35	0.12
Per cent of plants affected with interveinal necrosis	44	43	7	48	3	15	12
Chemical analysis of leaves[b]							
Mg (% dry wt.)	0.14	0.16	0.34	0.15	0.28	0.21	
Ca (% dry wt.)	0.26	0.44	0.12	0.24	0.46	0.35	
K (% dry wt.)	3.26	3.00	2.74	3.57	2.73	2.92	
Soil pH[c]	5.08	5.64	5.11	5.08	5.63	5.64	0.10

[a]Least significant difference.

[b]Averages of 2 composite samples from the 6 replications of each treatment.

[c]Averages for 5 of the 6 replications, due to the loss of 3 samples in replication 1.

MULCHING FOR CACAO

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INTRODUCTION

The term mulch in this paper is taken to refer solely to the application of vegetable matter, brought from elsewhere, to the surface of the soil. The mulch may be grown specially, or may be some organic waste product. (Green manuring, cover cropping, dust mulching, trench mulching and stubble mulching are specifically excluded).

A great deal of experimental work has been carried out on the effects of mulches on crop production and on soil conditions, both in temperate regions (particularly the U.S.A.), and to a lesser extent in the tropics. It is not proposed to attempt a review of the extensive literature on the subject, particularly as the Commonwealth Bureaux of Soil Science and of Horticulture and Plantation Crops are now preparing a Technical Communication on mulching. Rather it is proposed to discuss briefly the effects of mulches on the soil and the possible application of the practice to cacao growing.

THE EFFECTS OF MULCH ON THE SOIL

The many changes in soil properties which have been demonstrated to follow mulching may be grouped into physical and chemical effects.

It has frequently been shown that the number and stability of large soil aggregates occurring in the top few inches of the soil is increased by mulching. That is, structure and crumbiness, and hence aeration, are improved by the practice. These results may be atributed to the contribution of organic matter from the decomposed mulch, which helps to form and tends to stabilise soil aggregates, and to the protection of the soil surface from the destructive impact of rain. Mulching is frequently advocated as a measure for soil and

water conservation, since it considerably reduces run-off and erosion on sloping land, and has been shown to reduce water loss by evaporation since it protects the soil from moving air. Conversely, it has been claimed that mulches intercept and re-evaporate a considerable fraction of the rain, thus preventing too much water reaching the soil during excessively rainy periods. Both these effects must operate together; which will predominate will depend on climatic and microclimatic conditions, and the nature of the mulch and the physical condition of the soil. Conflicting results are reported in the literature. It seems likely that under many conditions mulch may act as a regulator of the amount of moisture in the soil, preventing excessively wet or excessively dry soil conditions. Mulches have been shown to regulate the temperature of the surface soil, preventing extremely low or high temperatures which may obtain in the absence of mulch.

The obvious chemical effect of mulches is the direct provision of plant nutrients, including major, minor and trace elements. Potassium is probably rapidly released in an immediately available form, phosphorus partly as phosphate, and partly as organo-phosphorus compounds, which are later slowly mineralised, and nitrogen largely as proteins which undergo bacterial transformation to nitrate. Trace elements may frequently be present in complex organic combinations and then be slowly mineralised and become available to plants before "fixation".

A possible advantage possessed by mulches over commercial fertilisers is the slow liberation of plant nutrients as the mulch decomposes, so that the plant can utilise the nutrients as they are released, and there is less possibility of loss by leaching and fixation. In addition, mulches have been shown to have an effect on the availability of plant nutrients already present in the soil. For example, the potassium contents of some soils have been shown to increase under mulches far more than can be explained by the potassium content of the mulch, and this has been attributed to protection of the soil from alternate wetting and drying, which is known to increase potassium fixation. The effects of organic acids and carbon dioxide produced by decomposing mulches on the availability of potassium and phosphorus, and in decomposing soil minerals, have also been cited. Again

the increased organic matter content of soils under mulches may increase the ability of the soil to retain exchangeable bases.

Among detrimental effects attributed to mulches have been that certain closely-packed materials, such as sawdust, if applied too thickly, may become waterlogged during wet periods and so actually seriously reduce aeration. It has frequently been observed that applications of fresh vegetable matter cause an immediate and drastic reduction in the nitrate level in the soil, and that a crop thus treated shows severe nitrogen deficiency symptoms. Large amounts of additional nitrogen fertiliser are often needed to counteract this effect. The deficiency of nitrogen only seems to occur, however, immediately after the application of a mulch having a high carbon:nitrogen ratio. As soon as decomposition of the mulch has gone on to such an extent that a layer of decomposing mulch of lower carbon:nitrogen ration (say 15) exists in contact with the soil, the nitrate level again becomes adequate, (although possibly lower than previously), and is not further lowered by the application of more mulch. The additional nitrogen supplied by the mulch should then gradually become available to the crop. Nitrate status is affected by a variety of factors, including moisture conditions, and possibly temperature and insolation, so that the process is complicated, but it has been shown that, although nitrate levels may be reduced under a mulch, the production of nitrate after the initial depression is rapid enough to support a larger crop than in the absence of mulch.

There are innumerable reports in the literature of the beneficial effects on crop yields and crop quality resulting from mulching. It can be seen that the effects on soil conditions can be many and various, and it is frequently difficult to decide which combination of factors has been responsible for a particular crop response. Many conflicting results are reported, and much of the variation is doubtless due to different kinds of mulch, methods of application and climatic and soil conditions. In the tropics, the rate of oxidation and decomposition of organic matter is much faster than in temperate regions, so that several writers have suggested that the sole contribution of mulches in the tropics may

be the direct provision of nutrients.

SOME INVESTIGATIONS ON MULCHING

Many of the effects of mulches on soil conditions have been investigated at I.C.T.A., particularly in connection with cacao cultivation. On an alluvial sandy-loam soil growing cacao, records over a period of two years showed that a mulch of sugar-cane bagasse kept the soil almost consistently drier than the "bare" soil in both wet and dry seasons, except that for a short period at the height of the dry season, the bare soil dried out excessively, (soil moisture was below "wilting point"), and more than the mulched soil (Hardy, unpublished results). In an experiment at St. Augustine, a grass mulch on a silty-loam soil kept the soil moister during the dry season and drier during the wet season, but, on a heavy alluvial silty-clay soil growing cacao, a mulch of elephant grass kept the top-soil slightly moister under the mulch throughout the year (Wasowicz and Havord, 1951). Griffith (1952) has demonstrated the effect of a vegetable mulch in intercepting rain.

In an experiment in which young cacao growing in a sandy-loam is being mulched with sugar-cane bagasse and cut bush, the writer has demonstrated that crumb stability in the top one inch layer of soil was markedly increased by both mulches after three years' application at the rate of 30 and 25 tons per acre respectively. The effect was demonstrated by a modification of the water drop impact method of Smith and Cernuda (1951). A stability index was calculated by dividing the original weight (air-dry) of an aggregate into its weight after subjecting to the impact of 60 water drops each of 0.1 ml. falling from a height of 60 cm. at one drop per second. In the same experiment, it was demonstrated that the percentage pore-space, and content of organic matter in the top inch of soil were increased by both mulches, and particularly by the bagasse mulch. The total nitrogen content was also increased, but equally by both mulches, so that the carbon:nitrogen ratio was higher under the bagasse mulch but little affected by the bush

mulch. These results are summarised in the table below:

EFFECT OF MULCHES ON SOIL CONDITIONS IN THE TOP INCH LAYER OF SOIL.

	Bagasse mulch	Bush Mulch	Control	Least significant differences
Stability index	0.634	0.629	0.476	0.128 for P = .01
Total pore-space (volume percent	70.2	65.4	61.1	3.5 for P = .05 4.7 for P = .01
Organic matter (percent)	9.57	7.13	5.57	1.32 for P = .05 1.76 for P = .01
Total nitrogen (percent)	0.353	0.352	0.272	0.063 for P = .01
Carbon:nitrogen ratio	15.84	11.77	11.86	2.14 for P = .01

It has not been possible to demonstrate changes in potassium or phosphate status in this experiment, owing to wide variations between plots, although statistically non-significant trends towards increased status are apparent on the bush mulched plots. However, in the experiment cited earlier and described by Wasowicz and Havord (1951), it was shown that a grass mulch, in addition to improving the organic matter and nitrogen status of the top six inches of soil, increased the phosphate status and particularly the potassium status of the soil very greatly, the increases amounting to about 50 percent and 100 percent respectively after six years of mulching. The unmulched soils had received fertilisers in an attempt to balance the major nutrients contained in the mulch. In addition, the mulch had made conditions in the top six-inches of soil more favourable for nitrification.

Earlier, McDonald (1935) had also demonstrated that the application of mulch to cacao fields resulted in an

increase in nitrate levels and moisture content. Nitrate status was not lowered immediately upon application of the mulch, as a layer of decomposing litter was already present on the soil surface. Daily temperature fluctuations were reduced. In the case of yet another early experiment on mulching cacao carried out in Dominica, Hardy (1941) was able to prove that the responses could have been explained solely by the major nutrient content of the mulches.

T. E. Wasowicz and the writer recently conducted experiments which demonstrated that various mulches were effective in reducing run-off and increasing percolation of rain water. A sandy-loam soil was placed in large tins and arranged so that the surface was exposed at an angle of about 10° to the horizontal. Mulches of bagasse, grass, cacao leaves, sawdust and gravel were applied to duplicate tins, and two had bare soil, and the percentage of the rain water which ran off the surface and that which percolated through the soil were determined twelve times during a period of 18 weeks. The results are summarised below:

EFFECT OF MULCHES ON RUN-OFF OF RAIN-WATER

	Bare soil	Bagasse	Grass	Leaves	Sawdust	Gravel
Mean percent percolated	21.0	54.4	63.3	67.7	57.3	63.5
Mean percent run-off	20.2	7.2	7.4	8.6	8.2	11.9

Least significant differences

Percolation results:	Bare v. Mulch:	16.7	(P = .01)
	Within Mulches:	4.4	(P = .05)
Run-off results:	Bare v. Mulch :	12.0	(P = .05)
	Within Mulches:	Not significant	

MULCHING AND CACAO

We may now consider the circumstances in which mulching is likely to be a beneficial and an economically sound

practice in commercial cacao growing.

Soil conditions in relation to cacao production should always be borne in mind when considering mulching cacao. It is unlikely that mulching would be worth while on a soil having intrinsically good physical structure in the top foot layer and reasonably well supplied with soil organic matter. A good physical structure should provide adequate aeration, that is, over 10 percent non-capillary pore space, with free or only slightly impeded drainage but adequate clay content to retain some moisture during drought. The soil should not be unduly susceptible to erosion. In such a soil, increased yields are more likely to be obtained economically by the use of commercial fertilisers.

Mulches are more likely to be effective in the improvement of soils which have suffered deterioration through past use. Cacao is normally grown in areas in which the natural vegetation was several-storey Tropical Evergreen Seasonal Forest, and its natural habitat was such forest. These forests can and often have developed on intrinsically poor soils over countless generations, through concentrating plant nutrients and organic matter into a relatively shallow surface humic layer. The layer is protected by a natural mulch of forest litter and by dense undergrowth, and reaches a state of equilibrium, replenishment and decay keeping pace. Like the other forest trees, cacao very largely subsists on this surface layer, which has excellent physical properties and is rich in nutrients. When the forest is felled or thinned and planted to a crop, even to a tree crop like cacao with overhead shade, the density of the vegetation is drastically reduced and the equilibrium is disturbed. The humic layer begins to diminish in thickness, and after a considerable time under the crop, in the absence of cultural techniques designed to maintain the equilibrium, deterioration in this humic layer may proceed so far that the crop is no longer economic. Pests and diseases and neglect occasioned periods of low prices may accelerate the decline. If the crop is clearfelled for replanting, the soil deterioration is vastly accelerated, particularly if a food crop is grown before replanting.

The problem may then be to re-establish cacao on such deteriorated soils. Such is, in fact, the position in most of the cacao growing areas of Trinidad today. The problem is being approached there by seeking to apply modern methods of orchard cultivation to cacao, and among the techniques available are the use of fertilisers and manures, soil tillage, the control of shade and atmospheric environment, drainage and irrigation where necessary, selection and breeding of high bearing, high quality disease resistant varieties, direct control of pests and diseases, and so on. Mulching is an attractive way of manuring, since by virtue of the physical and chemical effects already discussed it might be expected to restore just those desirable properties in the surface few inches of the soil which were present under the forest and have since been lost.

In this connection, it is frequently thought that mulching should never be necessary for cacao because of the constant leaf and twig fall which seems to keep the soil constantly covered with litter, but it should be borne in mind that this litter fall is of a different kind and far less in amount than that from the natural climax forest, and that, owing to the rapid decay of organic matter obtaining in the tropics, the equilibrium development of the litter and humic layer may be insufficient, particularly where growth is limited by soil factors such as those already outlined.

Mulching is a very expensive operation, and in fact is frequently rejected outright for this reason. It would obviously be hardly feasible to mulch a cacao estate of several hundred acres thoroughly and regularly. Apart from labour costs for spreading the mulch, sufficient labour may not be available when needed, although the employment of mechanical mulch cutters and tractor-drawn carts may help considerably. If a mulch is specially grown for the purpose on land which might otherwise have been used for cacao, then the yield must be more than doubled for the practice to be economic, for nearly as large an area will be required to provide mulch as the area under cacao. If mulch is brought from afar, say as sawdust, wood chippings or bagasse, transport costs may be high.

However mulching may well be a paying proposition if carried out on the small scale, say on 10 or 20 acres of land. It may then be possible to obtain sufficient mulch from traces, field edges, hedges, low lying, exposed, or rocky spots or places of difficult relief. If transport is maintained to carry crop to the marketing centre, it could perhaps bring mulches, such as sawdust, on the return journeys. Such materials are often available free, requiring transport only. In other words, mulching is more likely to be beneficial for the highly intensive cultivation of small areas of cacao on soils not intrinsically ideal, and so might appeal to the small proprietor or peasant. Nurseries may also be well worth mulching.

It should be borne in mind that mulching may not be necessary throughout the life of the crop. Once a surface soil layer having the required physical and chemical properties has been developed and cacao roots have been able to ramify within it, it may be possible to replace mulching partially or completely by cheaper commercial fertilisers, whereas it would have been wasteful to apply the fertilisers to a soil which had physical limitations such as prevent roots from taking advantage of the fertilisers.

So far, little experimental evidence has been obtained on the yield responses obtainable from mulching cacao, but experiments now in progress at I.C.T.A. are expected soon to provide this. The results of an experiment already cited have been published by T. E. Wasowicz and the writer (1951), and were encouraging although, owing to war-time and post-war restrictions, they are not decisive. A number of new field experiments have been initiated (Havord, 1951, 1952) to test various forms of mulching, and the Grenada Department of Agriculture has also begun similar trials. All are planted with clonal cacao. The oldest of these, planted in 1949, gave its first recordable crop in 1952/53, but the results were inconclusive owing to wide variations between the performances of the clones used, although a bush mulch and to a lesser extent bagasse mulch showed tendencies (not significant) to increase yields.

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Suelos/3

One estate in Trinidad has for three years been regularly mulching clonal cacao of all ages up to nine years, using sawdust which has been previously been employed as bedding in stables. The sawdust is obtained free of charge, and conveyed 5 miles, using transport required to convey the crops. A neighbouring estate has similar cacao not being mulched. Both estates are on similar soil (a dete iorated alluvial silty-clay) both have frequent drains, and both apply commercial fertilisers to the crop. The mulched fields have développed a marked humic crumb layer some 2 inches thick, high (over 20 percent) in organic matter and rich in nitrogen, phosphate and potash, and having excellent physical properties, ith a thick mat of cacao roots developed in it. The nearby unmulched fields have little or no humic crumb and very little root mat, although most of the cacao roots are confined to the surface few inches of the soil. The nutrient status of the "hard" soil (beneath the crumb and root mat) is higher in the mulched fields, and the rate of water infiltration is greater under the mulch, indicating superior structure. The yields of clonal cacao from the mulched fields were approximately twice those from similar aged trees in the unmulched fields. This result of course carries no statistical significance, being merely a field to field comparison.

CONCLUSION

It is not intended that this discussion should be considered a recommendation for the immediate adoption of mulching for cacao. So far, insufficient evidence has been obtained on the responses to be expected and the economic gains to be realised from the practice to permit such recommendations to be made. Nevertheless, it is stressed that the possibilities of muclhing, in the conditions and circumstances outlined, be fully explored by further experimental work. In such experimental work, care should be taken to compare the responses obtained from mulches with those from equivalent amounts of commercial fertilisers, and to investigate fully all the economic aspects of the practice.

5RTIC/Doc.5
Suelos/3

SUMMARY

The advantages and disadvantages of mulches are discussed in a general way. Some early cacao mulching experiments are cited in which crumb stability in the top inch of the soil, organic matter, pore space, total nitrogen and moisture content of the soil increased and temperature fluctuations of the soil were reduced. In natural forests there exists a delicate equilibrium between the organic humic layer laid down by the trees themselves and the depletion of this layer than breakdown and uptake by growing trees. When forest trees are cleared and cacao planted the equilibrium is upset, since cacao trees do not lay down a humic layer as rapidly as a natural forest. Soil deterioration may be accelerated. On some soils with good physical and chemical properties it would be more economical and to better advantage to make chemical fertiliser amendments. Although experimental evidence on mulching cacao is insufficient, preliminary results were encouraging. (A.E.)

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MEJORES PREPARACIONES HORMONALES PARA EL ENRAIZAMIENTO DE LAS ESTACAS DE CACAO

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El uso de las hormonas en la propagación de cacao por estacas es una práctica muy conocida y popular en todos los países donde se hacen plantaciones clonales. Por lo general se utiliza como estimulante del enraizamiento el ácido indolebutírico en soluciones hidroalcohólicas, mezclado con talco o en preparaciones comerciales, como el "Hormodin" de la casa Merk, etc. Las preferencias varían, pero han sido pocos los trabajos experimentales hechos con el propósito de determinar la mejor fórmula hormonal y el mejor método de aplicación para el enraizamiento de las estacas. La mayoría de las recomendaciones encontradas en la literatura (2, 3, 6) se basa en ensayos preliminares donde solamente se incluyó un limitado número de tratamientos. Evans (5) recientemente ha hecho un estudio más extensivo, con gran número de tratamientos, y en sus conclusiones finales recomienda la mezcla de ácido indolebutírico al 0.3% con ácido naftalenecético al 0.3%, en alcohol al 50%, como la fórmula más favorable para el enraizamiento de las estacas. Sin embargo, esa recomendación de Evans no se puede aceptar sino con reserva ya que los resultados experimentales no han sido sometidos al análisis estadístico.

En el Instituto Interamericano de Ciencias Agrícolas, Turrialba, Costa Rica, durante los últimos tres años, se ha llevado a cabo un gran número de experimentos con el propósito de determinar la mejor fórmula hormonal para el enraizamiento de las estacas de cacao. En varios experimentos se incluyeron algunos productos comerciales de uso corriente y se estudió también la posibilidad de disminuir las pérdidas de estacas por enfermedades en los propagadores, por medio de mezclas hormonales que contenían fungicidas, conforme ya fué experimentado con buenos resultados por Doran (4), en otras especies leñosas.

Este trabajo reune los resultados de los experimentos más concluyentes realizados hasta diciembre de 1953.

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MATERIALES Y METODOS

Todos los experimentos fueron conducidos en propagadores del tipo "Turrialba-2" o "Turrialba - 3", descritos por Alvim (1), usándose como medio enraizante el aserrín de madera.

Para mayor uniformidad del material se emplearon estacas de una sola hoja (excepto en un único caso), provenientes del segundo al cuarto nudo de la última brotación madura. Varios clones fueron utilizados en los experimentos, algunos de difícil enraizamiento como el U.F. 613 y otros de fácil enraizamiento como el U.F. 221, pero cada experimento incluyó solamente un clon. La mitad apical de la hoja fué previamente cortada con tijera, para facilitar su acomodación en las cajas propagadoras.

Antes de la aplicación de los tratamientos, las estacas fueron primeramente amontonadas y después distribuídas una por una, por sorteo, entre los varios tratamientos. Con una navaja afilada se arreglaba el corte de la base de la estaca antes de la aplicación de las mezclas hormonales.

Se experimentaron mezclas hormonales en alcohol al 60% o en talco inerte. En ambos casos la aplicación se hacía por inmersión rápida (más o menos un segundo), tratando solamente la base de la estaca hasta la altura de 2 ó 3 mm.

Para afirmar las estacas en los propagadores, en posición ligeramente inclinada hacia atrás, se utilizaron reglas de madera clavadas transversalmente sobre las cajas propagadoras.

En todos los experimentos se utilizaron diseños de bloque al azar, con 5 ó más repeticiones y 5 ó más estacas por parcela. Se presentará con los resultados experimentales los detalles sobre los tratamientos utilizados.

Los resultados fueron analizados para porcentaje de enraizamiento, porcentaje de estacas muertas, número de raíces primarias y largo total de raíces primarias, según mediciones con regla milimetrada.

RESULTADOS EXPERIMENTALES

Los resultados no se presentan en el orden de la realización de los trabajos, sino más bien por grupo de experimentos, de acuerdo con los asuntos estudiados.

1. Efecto comparativo del ácido indolebutírico, ácido naftalenoacético y naftalenoacetamida.

En el cuadro 1 se encuentran los resultados de un experimento con el clon U. F. 667; en este experimento se procuró comparar los efectos del ácido indolebutírico (AIB), del ácido naftalenoacético (ANA), de la naftalenoacetamida (NAA), todos a la concentración de 0,8% en alcohol de 60%, y también del producto comercial en polvo conocido como Hormodin Merk N° 2; este producto comercial, que es muy usado en los centros de propagación de la "United Fruit", en Costa Rica, contiene ácido indolebutírico como ingrediente activo. Se utilizó un diseño experimental de bloques al azar, con 10 estacas por parcela y 4 repeticiones. Las estacas se pusieron en el propagador el 24 de septiembre y los resultados se obtuvieron el 23 de octubre, es decir, 29 días después.

Respecto al número de estacas enraizadas o porcentaje de enraizamiento, se ve que el AIB al 0,8% y el Hormodin dieron resultados significativamente superiores a los de los demás tratamientos y a los del testigo y no presentaron diferencias significativas entre sí. El AIB al 0,8% fué el mejor tratamiento en cuanto al número y longitud total de las raíces producidas, con diferencias altamente significativas sobre los demás tratamientos, inclusive el Hormodin. No hubo diferencia significativa entre NAA al 0,8% y el testigo, en ninguno de los resultados.

Cuadro 1. Efecto comparativo del ácido indolebutírico (AIB), ácido naftalenoacético (ANA), y naftalenoacetamida (NAA), y Hormodin N° 2 en el enraizamiento de estacas de cacao del clon U. F. 667. Número de estacas por tratamiento= 40. Finca La Lola 24 de septiembre a 23 de octubre de 1952.

Tratamientos	N° Estacas Muertas	Estacas enraizadas		Raices Primarias	
		N°	%(40-100%)	N°	Longitud
Testigo	6	6	15%	9	11,5
AIB 0,8%	10	24	60%	160	602,2
ANA 0,8%	11	7	17,5%	60	158,3
NAA 0,8%	16	12	30,0%	36	67,3
Hormodin N°2	5	21	52,5%	70	182,0
DMS al 5%	n.s.	8,4	-	60,8	102,5
" al 1%	n.s.	11,7	-	85,2	128,2

de solubilidad del AIB en alcohol al 60%) incluyéndose además la hormona comercial Hormodin N° 2 y un testigo sin tratamiento. El clon empleado fué el U. F. 650. Se utilizaron 4 repeticiones con 5 estacas por parcela, en bloque al azar. Los resultados se presentan en el cuadro 3.

Veáse que las concentraciones 0,6, 0,8 y 1,0% fueron superiores al testigo respecto al número de estacas enraizadas, y que las diferencias entre el testigo y el Hormodin no fueron significativas en ninguno de los resultados. Las concentraciones 0,6, 0,8 y 1,0% fueron superiores a todos los demás tratamientos respecto al tamaño de las raíces. El número de raíces fué mayor en las concentraciones 0,8 y 1,0%.

Como el ácido indolebutírico es un producto relativamente caro (US$1,70 per gm.) sería deseable sustituirlo con el ácido naftalenoacético, aunque fuera necesario usar concentraciones más elevadas (el ANA es cerca de 20 veces más barato por unidad de peso). Se realizó un experimento comparando el ácido indolebutírico al 0,8% con el ácido naftalenoacético (más soluble) en las concentraciones de 0,8%, 1,2%, 1,6% y 2,0%.

Cuadro N° 3. Efecto comparativo del ácido indolebutírico (AIB) en cinco concentraciones y del Hormodin en el enraizamiento de estacas de cacao del clon U. F. 650. Número de estacas por tratamiento = 20. Finca La Lola, 24 de agosto a 13 de septiembre de 1951.

Tratamientos	N° Estacas Muertas	Estacas enraizadas		Raíces primarias	
		N°	%(20=100%)	N°	Longitud cm.
Testigo	5	6	30%	17	40,4
Hormodin	6	9	45%	30	158,1
AIB 0,2%	5	11	55%	59	215,8
AIB 0,4%	9	10	50%	55	205,6
AIB 0,6%	4	13	65%	91	402,6
AIB 0,8%	4	15	75%	138	407,4
AIB 1,0%	4	15	75%	143	491,7
DMS al 5%	n.s.	6,7	-	42,4	163,3
" al 1%	n.s.	10,3	-	64,8	2 9,8

Cuadro N° 4. Efecto de la concentración del ácido naftalenoacético (ANA), en comparación con el ácido indolebutírico al 0,8% en el enraizamiento de estacas de cacao. Clon U.F. 12. Número de estacas por tratamiento = 20. Turrialba, Costa Rica del 7 de noviembre a 3 de diciembre de 1952.

Tratamientos	N° Estacas Muertas	Estacas enraizadas		Raíces Primarias	
		N°	%(20=100%)	N°	Longitud cm.
AIB 0,8%	7	14	70%	143	205,3
ANA 0,8%	10	9	45%	42	70,2
ANA 1,2%	14	8	40%	38	63,6
ANA 1,6%	9	8	40%	43	92,9
ANA 2,0%	10	6	30%	27	47,4
DMS al 5%	n.s.	4,87	-	43,5	71,3
DMS al 1%	n.s.	6,10	-	54,3	89,1

Los resultados resumidos en el cuadro 4, muestran claramente la superioridad del AIB bajo todos los puntos de vista sobre cualquiera de las concentraciones usadas del ANA. No se puede recomendar el ANA como sustituto del AIB, aún en concentraciones elevadas.

Evans (5) recomienda la mezcla de AIB al 0,3% y con ANA al 0,3% como superior al AIB aplicado sólo a la concentración de 0,6% o al 0,8%. Para estudiar este asunto se realizó un experimento con 10 tratamientos dentro de los cuales se incluyeron las mezclas AIB 0,3% + ANA 0,3%, AIB 0,4% + ANA, 0,4% , y AIB 0,4% + NAA 0,4%. La relación de los tratamientos se presentan en el cuadro 5 donde también se reúnen los resultados. Se empleó el clon U. F. 221, relativamente fácil de enraizar, utilizándose 5 estacas por parcela en bloques al azar, con siete repeticiones.

Respecto al efecto de la concentración del AIB, los resultados confirman las conclusiones de los experimentos anteriores. Las mezclas hormonales prácticamente tuvieron el mismo efecto del Hormodin, apenas ligeramente superior al testigo, y respecto al crecimiento de las raíces fueron significativamente inferior al AIB aplicado sólo en cualquiera de las concentraciones arriba de 0,6%.

Cuadro N° 5. Efectos comparativos del ácido indolebutírico (AIB) en 5 concentraciones, mezclas de indolebutírico con ácido naftalenoacético (ANA) y con naftalenoacetamida (NAA) y del Hormodin en el enraizamiento de estacas de cacao del clon U. F. 221. Número de estacas por tatamiento =35 . Finca La Lola, 22 de marzo a 18 de junio de 1953.

Tratamientos	N° Estacas Muertas	Estacas enraizadas		Raíces primarias	
		N°	%(35=100%)	N°	Longitud cm.
Testigo	5	14	40,00%	24	56,7
Hormodin	5	24	68,57%	96	200,8
AIB 0,2%	4	28	80,00%	120	202,7
AIB 0,4%	1	30	85,71%	173	465,4
AIB 0,6%	11	22	62,85%	194	631,8
AIB 0,7	6	25	71,42%	239	736,2
AIB 0,8%	5	27	77,14%	277	825,8
AIB 0,3% + ANA 0,3%	13	16	45,71%	58	78,2
AIB 0,4% + ANA 0,4%	11	17	48,57%	103	176,2
AIB 0,4% + NAA 0,4%	4	25	71,42%	138	323,1
DMS al 5%	n.s.	n.s.	-	74,1	195,2
" al 1%	n.s.	n.s.	-	98,8	273,0

En el centro de propagación de la finca La Lola se ha hecho también un ensayo extensivo empleando estacas de 3 ó 4 hojas, divididas en tres grupos de 200, comparando los tratamientos: AIB 0,8%, AIB 0,4% + ANA 0,4% y Hormodin N° 2. Se empleó el clon U. F 667. Los resultados, presentados en el cuadro 6, no han sido analizados estadísticamente, pero indican claramente la superioridad del AIB 0,8% sobre los otros tratamientos, en cuanto al número de raíces producidas. El porcentaje de enraizamiento ha sido ligeramente inferior en el tratamiento con Hormodin. No se midió el largo de las raíces en este ensayo.

Cuadro N° 6. Comparación entre el ácido indolebutírico (AIB) al 0,8% mezcla de ácido indolebutírico (AIB) 0,4% con ácido naftalenoacético 0,4% y Hormodin N° 2, en el enraizamiento del clon U. F. 667. Número de estacas por tratamiento = 200. Finca La Lola del 2 de abril al 8 de mayo de 1952.

Tratamientos	% de enraizamiento	N° promedio de raíces por estaca.
AIB 0,8%	63,5%	9,08
AIB 0,4% + ANA 0,4%	64,0%	7,66
Hormodin	56,0%	4,26

3. Preparaciones hormonales en talco con adición de fungicidas.

En los experimentos anteriores los autores hicieron todas las preparaciones hormonales en solución hidroalcohólica. Estas soluciones tienen la desventaja de evaporar con facilidad, y sin duda para el uso extensivo son menos prácticas que las preparaciones en polvo. Se pueden preparar con relativa facilidad mezclas hormonales en talco, pero primero interesaría determinar si dichas preparaciones son tan eficientes como las soluciones hidroalcohólicas. Las preparaciones en talco se pueden mezclar fácilmente con algunos fungicidas en polvo, resultando un producto que no solamente actúa como estimulante del enraizamiento sino que también evita la intervención de microorganismos parasitarios que ocurre en los propagadores (4).

El cuadro 7 presenta los resultados de un experimento en que se comparan los efectos del AIB a 0,8% y 1,2% en talco y en solución hidroalcohólica, de las mezclas de AIB en talco con los fungicidas "Perenox", "SR-406" (ahora vendido con el nombre de Orthocide-50) y "Phygon XL", y de las hormonas comerciales: Hormodin N° 2 de la casa Merk y "Seradix N° 3" de la casa May and Baker.

Cuadro N° 7. Efectos comparativos del ácido indolebutírico (AIB) en soluciones hidroalcohólicas y en polvo "Hormodin", "Seradix" y mezclas en talco de AIB con algunos fungicidas. Clon U. F. 12 número de estacas por tramiento = 24. Finca La Lola del 1° al 28 de octubre de 1953.

Tratamientos	N° Estacas Muertas	Estacas enraizadas		Raíces primarias	
		N°	%(24=100%)	N°	Longitud cm.
Testigo	2	1	4,16%	6	5,9
Hormodin	3	15	62,50%	89	8,9
Seradix	3	13	54,16%	254	677,5
AIB 0,8% en alcohol	7	17	70,83%	226	646,4
AIB 0,8% en talco	6	16	66,66%	216	676,2
AIB 1,2% en alcohol	6	14	58,33%	151	510,2
AIB 1,2% en talco	8	16	66,66%	236	884,2
AIB 0,8% en talco más 1/3 Perenox	3	7	29,16%	24	28,5
AIB 0,8% en talco más 1/3 SR-406	2	22	91,66%	224	515,4
AIB 0,8% en talco más 1/3 Phygon XL	4	20	83,33%	196	433,1
DMS al 5%	n.s.	7,65	-	137,9	487,1
" al 1%	n.s.	10,33	-	186,2	657,8

De los resultados obtenidos se concluye que las preparaciones en talco son tan eficientes como las soluciones hidroalcohólicas. La adición del "Perenox" en la mezcla de talco redujo significativamente el número de estacas enraizadas y el número y crecimiento de las raíces primarias. Por otro lado, la adición del SR-406 y del Phygon aparentemente aumentaron el número de estacas enraizadas, aunque las diferencias solamente fueron significativas para el SR-406 con relación al testigo, al Perenox, y a la solución hidroalcohólica con 1,2% de AIB.

Se hizo un nuevo experimento incluyendo solamente fungicidas orgánicos: Zerlate, Fermate, SR-406 y Phygon. Para separar el efecto del fungicida del efedto de la hormona se incluyeron tratamientos con AIB y sin AIB. El clon empleado fué el U. F. 221.

El Phygon XL aumentó significativamente el número de estacas enraizadas en comparación con el testigo, el Zerlate y el Fermate. El SR-406 fué prácticamente igual al Phygon, pero fué significativamente superior solamente al Zerlate. No hubo efecto significativo de ninguno de los fungicidas en relación con el número y crecimiento de raíces primarias. El AIB, como se esperaba, aumentó significativamente el número de estacas enraizadas, el número y crecimiento de raíces primarias en casi todos los casos. El análisis estadístico reveló, además, que no hubo interacción entre los efectos de los fungicidas y de la hormona.

Cuadro N° 8. Efecto comparativo de los fungicidas Zerlate, Fermate, Phygon XL, y SR-406 (Orthocide-50) mezclados en talco con ácido indolebutírico (AIB) al 0,8%, y sin ácido indolebutírico. Clon 221. Número de estacas por tratamiento = 25. Turrialba, Costa Rica, del 28 de noviembre al 26 de diciembre de 1953.

Tratamientos		N° Estacas Muertas	Estacas Enraizadas		Raíces Primarias	
			N°	%(25=100%)	N°	Longitud cm
Talco sin fungicida	Con AIB	4	19	76%	84	136,5
	Sin AIB	4	14	56%	27	29,2
	Total	8	33	66%	111	165,7
Talco + Zerlate	Con AIB	3	20	80%	78	95,4
	Sin AIB	0	12	48%	31	23,7
	Total	3	32	64%	109	119,1
Talco + Fermate	Con AIB	2	21	84%	111	230,5
	Sin AIB	1	13	52%	25	14,6
	Total	3	34	68%	136	245,1
Talco + SR-406	Con AIB	0	25	100%	116	190,5
	Sin AIB	1	17	58%	45	38,4
	Total	1	42	84%	161	228,9
Talco + Phygon	Con AIB	1	24	96%	127	183,5
	Sin AIB	0	19	76%	47	46,2
	Total	1	44	88%	174	229,7
D.M.S. para fungicidas (Totales)	al 5%	n.s.	9,31	-	n.s.	n.s.
	al 1%	n.s.	12,48	-	n.s.	n.s.
D.M.S. para hormonas	al 5%	n.s.	6,58	-	52,8	135,1
	al 1%	n.s.	8,70	-	70,9	181,2

CONCLUSIONES Y RECOMENDACIONES

En los trabajos sobre el efecto de las hormonas en el enraizamiento de estacas, por lo general solo se considera el efecto de los tratamientos sobre el porcentaje de estacas enraizadas; pero no se aquilatan las diferencias en números de raíces producidas o en el crecimiento de las raíces. Se verificó en todos los experimentos del presente estudio que la influencia de las fitohormonas en el proceso de enraizamiento de las estacas se manifiesta en el número y crecimiento de las raíces mucho más que en el porcentaje de estacas enraizadas. Fué fácil observar, en un mismo experimento dos o más tratamientos aparentemente iguales respecto a su efecto sobre el porcentaje de enraizamiento y sin embargo muy distintos cuando se analizó el número y longitud de las raíces emitidas. El crecimiento de las raíces es sin duda un factor de gran interés práctico, ya que el período de enraizamiento es tanto más corto cuanto más rápidamente se desarrolla el sistema radicular; además desempeña papel importante en la sobrevivencia de las estacas después de trasplantadas. Se hace hincapié, de ese modo, en que no se puede juzgar la eficacia de un estimulante para el enraizamiento de estacas si no se considera su influencia sobre el desarrollo del sistema radicular junto con las observaciones sobre el porcentaje de enraizamiento. Dentro de este concepto es que se interpretarán los resultados del presente trabajo.

De las fitohormonas experimentales la más eficiente como estimulante del enraizamiento fué, sin duda, el AIB, y la concentración más recomendable para aplicaciones en inmersión rápida fué de 0,7 a 0,8%.

No hubo diferencias apreciables entre las preparaciones de AIB en solución hidroalcohólica y en talco, respecto a efectos sobre el enraizamiento, pero los autores consideran más recomendable las preparaciones en talco porque son más fáciles de manejar en los trabajos de campo y no necesitan precauciones contra pérdidas por evaporación.

Las mezclas de AIB con ANA, recomendadas por Evans (5) y empleadas en los centros de propagación de Trinidad, se probaron como muy inferiores al AIB aplicado sólo a las concentraciones de 0,6 a 1,0%. Del mismo modo el Hormodin N° 2 de la casa Merk, producto muy usado en varios centros de propagación de cacao, fué en comparación a los tratamientos experimentales en el trabajo, uno de los menos eficaces.

La adición de los fungicidas orgánicos Phygon XL y SR-406 (Orthocide-50) en la proporción de más o menos 1:3, en las

mezclas hormonales en talco, aumentó el porcentaje de estacas enraizadas. Esto posiblemente se debe al control de microorganismos que atacan la base de las estacas aunque también se puede pensar en la posibilidad de algún estímulo provocado por los ingredientes químicos de los propios fungicidas.

El fungicida "Perenox" a base de sulfato de cobre, disminuyó el porcentaje de enraizamiento. Posiblemente los fungicidas a base de metales tóxicos no sirven para la preparación de mezclas hormonales.

Como conclusión general, los autores recomiendan como mejores: las fórmulas con 0,7 ó 0,8% de ácido indolebutírico en mezcla de talco con Phygon o SR-406 a la proporción de 3:1. La preparación de la mezcla no ofrece dificultades y la puede hacer cualquier persona. A título de divulgación se describe a continuación el procedimiento para preparar 100 gramos de una mezcla con 0,7% de AIB en talco y Phygon en la proporción de 3:1.

a. Diluir 700 miligramos de ácido indolebutírico en más o menos 50 cm.^{3} de alcohol absoluto;

b. Mezclar con 65 ó 70 gramos de talco inerte, utilizando un recipiente de loza o vidrio y un bastonete agitador también de vidrio, hasta la formación de una pasta homogénea;

c. Dejar secar a la sombra durante uno o dos días;

d. Adicionar 30 ó 35 gramos de Phygon y mezclar hasta la formación de una mixtura homogénea;

e. Guardar en recipiente cerrado de metal o vidrio, al abrigo de la humedad.

SUMMARY

The authors present the results of several experiments comparing the effect of different formulations of root-inducing substances on cacao cuttings. Among the treatments were two commercial products; Merk's "Hormodin N° 2" and May and Baker's "Seradix B N° 3".

It was found that the best stimulant for rooting of the cuttings was indole-butyric acid at 0,7 or 0,8% in alcohol 60% or talc. The addition of the fungicides Phygon XL or SR-406 in

powder form to the talc formulation at the rate of 1:3 significantly increased the percentage of rooting. The commercial product "Hormodin" as well as the mixtures of indole-butyric acid and naphtalene-acetic acid recommended by others have proven to be much inferior to straight indole-butyric at 0,6 - 0,8%.

The authors recommend as the best formulation the powder mixture, 3:1, of talc and Phygon XL or talc and SR-506 with 0,7 or 0,8% of indole-butyric acid. The method of preparing this formulation is described.

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A NEW METHOD OF VEGETATIVE PROPAGATION

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Although the production of rooted cuttings of high yielding clones is now an established feature in progressive cacao growing areas, the techniques in use are such that the cost of a rooted cutting is, in general, rather high. A method has now been developed which aims at producing fairly large numbers of rooted plants at a great reduction in cost.

GENERAL DESCRIPTION

The method employs a glasshouse fitted with a centrifugal humidifier originally developed by Evans (1953) as a hardening chamber. This glasshouse is some 7 m. x 4 m. x 3 m. and is completely enclosed but not necessarily airtight. The roof is of "Windolite", a plastic material lighter than glass and requiring far lighter roof construction. The roof is shaded with camouflage netting to reduce the light intensity inside to some 25% of full light. The long sides run North-South to get the maximum penetration of morning and afternoon light.

The centrifugal humidifier is mounted high at one end and is a device for maintaining atmospheric humidity at 100% without appreciable droplet formation. The model in use employs a 1/4 H.P. electric motor and requires 30 to 35 litres of water per hour at a pressure of about 20 lbs/sq. inch.

Inside the glasshouse, aluminium angle strips are used in the construction of four tiers of shelves with 50 to 60 cm. vertical space between. Movable 5 cm. wide wooden slats are laid on the aluminium strips to carry the baskets for the plants. A central passage allows access to the shelves.

The cuttings are rooted in this glasshouse in the usual palm or bamboo baskets prepared as shown in Fig. I.

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A metal cylinder of 5 cm. diameter is placed in the basket and potting soil lightly tamped around it. The cylinder is then withdrawn and the space filled with the rooting medium-composted sawdust, coconut fibre residue, etc. The baskets are placed on the shelves in the glasshouse and the cuttings after preparation in the usual way are inserted about 7 cm. deep into the central core.

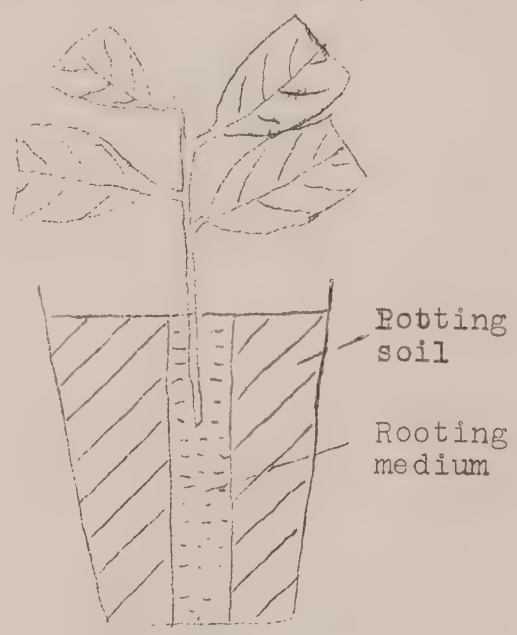

Fig. 1

The centrifugal humidifier is operated continuously during the hours of daylight, being turned off only during periods of rain. No other watering is necessary.

From about 24 days onwards, roots begin to emerge from the sides of the baskets and at this stage they can be removed to an open shaded site as established plants. The actual routine is to remove rooted plants at 28, 35 and 42 days. At the final examination, the cutting is gently pulled. If it comes away unrooted it is discarded. If it has rooted but roots have not emerged through the sides of the basket, it is placed with the others in the shaded greenhouse and examined one week later for establishment.

DISCUSSION

The method is straight forward. The centrifugal humidifier maintains the humidity at 100%, an essential feature in the propagation of cacao. At the same time there is the minimum of free water so that leaching of the soil in the baskets does not occur. The base of the cutting is in a rooting medium where conditions of aeration and water supply are very suitable for rooting. As the roots develop they grow into soil without any check in growth or possibility of damage such as occurs in the normal transplanting of rooted cuttings.

The reduction in labour requirement as compared with the orthodox methods is obvious. Handling and attention are reduced to a minimum. Moreover the capital cost of the glasshouse and humidifier is less than the equivalent capacity of closed concrete bins and hardeners.

Rooting efficiency is similar to results from closed bins. The capacity of the present unit is 2,500 plants per setting or 20,000 cuttings per year. At 75% efficiency this would give 15,000 plants a year for field planting. The centrifugal humidifier could operate a house of twice the length with a resultant doubling of output.

SUMMARY

(1) A method is described for producing rooted cacao cuttings in baskets in one operation at a substantial saving in cost as compared with the orthodox methods.

(2) The essential features are a glasshouse with a centrifugal humidifier to maintain 100% humidity and the use of baskets with a central core of rooting medium surrounded by potting soil. The cutting is inserted into the core and the roots develop into the soil.

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5RTIC/Doc.8
Prop./3

THE PIT METHOD OF ROOTING CACAO

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One of the most difficult modern agricultural practices in the tropics is the production of cacao plants by propagation from cuttings. A high degree of success may be obtained if expensive equipment and close personal attention is employed but often the cost are so great as to prohibit the production of large numbers of plants. A simple and cheap method of vegetative production is necessary to produce clonal plants in quantity in order to benefit the cacao producing countries of the world.

A progress report toward less expensive propagation entitled "The Economic Propagation of Cacao by the Asexual Method" was submitted by the writer at the Fourth Inter-American Cacao Conference held in Ecuador in 1952. The present report is a continuation of these studies and presents the results obtained in a new type propagation unit which is both cheaply constructed and operated.

The standard Trinidad propagation frame raised 2-1/2 to 3 feet above the ground surface and with relatively thin and uninsulated walls is subject to all the fluctuations in temperature of the surrounding air and in some cases where shading is incomplete, to direct radiation from the sun. The control of humidity is therefore difficult and semi-automatic watering devices are not applicable to this type of propagation unit.

The insulating value of the ground and the relative constant temperature of the surrounding earth stimulated the construction of a small propagation pit on the trial basis. This first pit was dug in January 1951. It was 20 inches deep, 3 feet wide, and 5 feet long. The rooting medium was 14 inches of sawdust and jute fabric was used for covers. A narrow outlet at the bottom of the pit provided drainage. Watering was done 3 to 4 times daily and as frequently as necessary to keep the jute covers constantly damp.

Table 1 shows the results in numbers and per cent

Table I

Pit-Type Unit					Conventional Trinidad Unit				
Cuttings entered	Cuttings rooted strong	Cuttings rooted poor	Rooting % strong	Rooting % total	Cuttings entered	Cuttings rooted strong	Cuttings rooted poor	Rooting % strong	Rooting % total
405	285	27	70.6	72.5	230	166	17	72.1	78.
310	207	34	66.	77.5	460	273		59.3	59.3
810	358	186	43.6	66.3	507	227	61	44.	65.8
433	282	6	70.	71.5	330	108		54.6	54.6
450	349		72.5	72.5	230	127		51.	51.
349	283	28	81.	89.	148	106		71.6	71.6
2,757	1,764	281	64.5	74.6	1,905	1,007	78	52.8	56.9

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of cuttings rooted in the pit-type propagation unit as compared to a standard conventional Trinidad frame used as a control.

On the basis of satisfactory performance of this trial pit, a larger one was constructed with an area of 289 square feet and a capacity for 6,000 cuttings.

This larger pit, is circular in outline and the diameter of 22 feet corresponds to the distance a simple type of rotary lawn sprinkler will throw water when mounted on a standard 3 feet above ground level in the center of the pit. Jute covers at ground level are supported by wires strung radially from the center to the periphery of the pit. The sprinkler is operated three times daily for 20 to 25 minute periods during the dry season and for 10 to 15 minute periods during the wet season. With some types of hard-wood sawdust, a longer watering period is necessary. It is also operated for brief intervals during the day as is necessary to keep the jute covers constantly wet. No overhead shade is used.

The propagator is obliged to walk on the sawdust rooting medium while setting cuttings but this tends only to firm the sawdust and no adverse effect has been noted. Naturally the propagator feet must be clean before entering so that pathogenic organisms will not be introduced in this manner.

Table II shows the results obtained in this giant circular pit under routine management. The per cent of rooting is lower than in the original small trial pit. The difference may be due to the lack of individual attention given to a large production unit as compared to the small experimental pit.

Table II

Cuttings entered	Cuttings rooted		Rooting %	
	Strong	Poor	Strong	Total
4,200	2,000	26	47.6	48.2
6,089	3,680	82	60.5	78.5
6,100	3,000	300	49.5	54.5
1,583	891	146	56.2	65.
5,408	3,060	185	56.5	60.
23,380	12,631	739	54.2	57.18

Under low-cost mass production methods the attainment of 50 per cent well rooted cuttings may be considered quite satisfactory. A higher per cent of cuttings rooted may be obtained but the extra facilities and attention would probably raise the cost of the clonal plants on an unit basis. Clones vary in their ability to root from cuttings, and environmental and seasonal conditions also influence rooting so the 50 per cent figure represents only an average.

Proper handling of the sawdust medium is important. New sawdust should be throughly wet by turning over while applying a gentle stream of water and then left to set at least overnight before setting the cuttings. Good drainage is essential. A trench should be dug below the pit to carry off any excess water. Gravel or other drainage material should be placed at the bottom of the pit below the sawdust. Rice hulls for slow drainage may be used but should be replaced with fresh hulls every 6 or 8 months when the sawdust is being changed.

The mortality of the rooted cuttings in the hardening off bins may be reduced if the cuttings are allowed to remain longer in the pits than the conventional 30 days. The loss drops from 5 to 10% for cuttings left only 30 days to 3 to 5% for cuttings left in the pit for 7 to 10 days more.

SUMMARY

A pit three by five feet was made twenty inches deep as a propagating unit to take advantage of the fact that the ground serves as a good insulator. A jute cover was used, and sawdust as the rooting medium. Watering was done tree or four times daily to keep the cover constantly damp. The rooting was better in the pit-type propagator than in the conventional Trinidad unit.

A larger pit twenty-two feet in diameter was built with a rotary lawn sprinkler mounted three feet above ground level. The sprinkler was operated three times daily for twenty to twenty-five minutes during dry periods and ten to fifteen minutes during wet periods. The sprinklers were also operated for brief periods during the day to keep the covers wet. No shade was used. Fifty-seven per cent rooting was obtained. (A.E.)

THE USE OF A PLASTIC RESIN FOR TRANSPLANTING CACAO*

F. L. Steve O'Rourke**

The extensive use of vegetatively propagated clones of cacao in commercial plantations has been greatly discouraged by the excessive mortality to plants experienced both during transportation and after transplanting to their permanent location in the field. Many devices are used in an attempt to reduce mortality to plants after field transplanting by providing shade and reducing air currents. Water loss by transpiration may be decreased by such means and a higher degree of survival assured.

Trees, legumes, and other plants are often established before the cacao is planted. Artificial shade is provided by stakihg large tropical leaves on the sunward and windward sides of newly set plants, leaves of the plants are pruned at time of transplanting, and even drastic pruning of both leaves and branches is practiced in some cases. In spite of these measures, mortality is often quite severe.

In 1948 Hamner, Gartner, and O'Rourke (2) indicated that a liquid plastic coating sprayed on the cut foliage of evergreen reduced water loss and extended the usefulness of these greens under hot and dry conditions. In 1949 Gartner, O'Rourke and Hamner (1) reported that summer transplanting of certain evergreen and deciduous trees could be successfully accomplished by spraying the trees with this liquid plastic resin before digging.

The plastic material, a vinyl resin latex known

* Acknowledgement: Thanks are due the B.F.Goodrich Chemical Co., Cleveland, Ohio for supplying the material used and to Sr. Alfredo Cruz, student of the Escuela Práctica de Agricultura Tropical, for work rendered in the transplanting experiment.

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as Goodrite V1-600*, is a water dispersible colloid containing about 51 per cent solids as prepared by the manufacturer. This stock emulsion is usually diluted with about 4 parts of water to form a suspension containing about 10 per cent solids, a concentration which is quite adequate for general spraying or dipping of woody plants. The addition of a small amount of wetting agent, such as 0.1 per cent sodium lauryl sulfate, reduces surface tension and assures a smooth even coverage of the foliage.

The vinyl resin emulsion has a milky color in suspension but dries rapidly after spraying to form a transparent glossy coat which add a slight sheen to the normal appearance of the foliage. A somewhat heavier coating can be obtained by allowing the first coat to dry for a few minutes and then applying a second one. It may be more rapid and efficient to dip the tops of small plants rather than to spray them.

The first use of V1-600 at the Estación Experimental Agrícola Tropical del Ecuador was in transplanting cacao seedlings from the seed bed to the field. This work was assigned as a student problem in January 1954. Unfortunately due to lack of material the number of plants used was quite limited. Uniform lots of seedlings were selected, treated, and planted on the same day. Comparisons were made between plants dipped once in a 10per cent suspension of V1-600, those dipped twice, those in which leaves and stem were enclosed in bags of polyethylene plastic cloth, and those untreated, in both sunny and shaded locations. The shade was furnished by large leaves of bijao (Calathae sp.) firmly held in place by two narrow bamboo stakes. The results of this test is shown in Table 1.

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* Manufactured by the B. F. Goodrich Chemical Company Rose Building, Cleveland 15, Ohio.

TABLE 1. EFFECT OF LIQUID PLASTIC VL-600 AND POLYETHYLENE BAGS ON SURVIVAL OF TRANS-PLANTED CACAO SEEDLINGS.

Date Planted	Number Plants per trt.	Number of Plants Alive After Ten Days in the Field							
				Treated with VL-600					
		Check in Sun	Check in Shade	One dip in Sun	One dip in shade	Two dips in Sun	Two dips in Shade	Polyethylene bag in sun	Polyethylene bag in shade
Feb. 5	10	0	8	3	10	7	7	1	10
Feb. 8	10	1	7	3	4	3	5	0	8
Feb. 9	10	1	0	0	6	4	8	0	8
Feb.10	10	1	1	4	3	2	6	2	7
Mar. 4	10	2	5	2	6	3	6	0	4
Mar. 5	10	2	9	3	10	3	8	2	2
Mar. 8	10	3	7	5	6	4	4	1	3
Mar.12	10	9	9	10	9	10	10	2	10
Mar.14	10	2	5	2	4	2	6	0	1
Mar.15	10	1	6	2	8	2	6	0	0
Mar.18	10	3	4	5	5	3	4	0	3
TOTAL	110	25	61	39	71	43	70	8	56
Per Cent		22.7	55.5	35.5	64.5	39.1	63.6	7.3	50.9

While the number of plants used in these unreplicated tests were so limited that it is not possible to draw definite conclusions, it is noteworthy that the plants which received a coating of VL-600 survived to a much greater degree than the controls in both sunny and shaded locations while those enclosed in polyethylene plastic bags were defi itely inferior in survival.

The increase in survival of those plants sprayed with VL-600 over the unsprayed in the sunny position may not be due entirely to chance. A shipment of 200 clonal cacao plants in canutos were sprayed with VL-600 at the Estación Tropical, taken to Guayaquil by launch, and then to the Milagro Station of the University of Guayaquil by truck. The mortality upon arrival was practically nonexistent. These plants were then set in quite dry soil without shade and again mortality was very low in spite of intense sunlight for several days after planting. Under ordinary conditions a high degree of mortality could be expected both during transportation and following planting under adverse conditions.

Another large shipment of clonal cacao plants were sprayed at the Estación Tropical and transported over the Andes to a distant valley by truck. These arrived at their destination two days later with very few dead plants. A similar shipment of untreated plants the previous year was badly damaged by the excessive transpiration suffered en route and subsequent wilting and drying.

Spraying with VL-600 before shipment or planting is now standard practice at the Estación Tropical. This anti-dessicant decreases water loss to such an extent that successful planting may be attained even far into the dry season. Tests to determine the degree of survival in the dry period of the year will be made at the Estación Tropical during the current year.

SUMMARY

The widespread use of vegetatively propagated clonal material is being handicapped by the very large transplanting losses incurred in spite of all precautions taken. In the transplanting of evergreens, losses

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appeared to be reduced by spraying the cut foliage with Goodrite VL-600, a venyl resin latex (diluted with 4 parts water and mixed with a wetting agent). An experiment in which cacao seedlings were treated and transplanted showed that seedlings treated with Goodrite survived better than those untreated on transplanted enclosed in Polyethylene plastic cloth bags, in both sunny and shady locations. Losses were so small in the shipment and transplanting of large lots of rooted cuttings that spraying with Goodrite is now standard practice at the Estación Experimental Tropical del Ecuador. (A.E.)

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ENSAYO COMPARATIVO ENTRE PERGAMINO DE CAFE Y ASERRIN DE MADERA COMO MEDIOS DE ENRAIZAMIENTO PARA ESTACAS DE CACAO

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El afán de tornar más fácil el proceso de propagación de cacao por estacas, con menores esfuerzos y disminuyendo el costo, ha movido a muchos para tratar de encontrar mejores medios de enraizamiento para las cajas de propagación.

Escamilla (3) ensayó por primera vez, con buenos resultados, la cáscara del café (pergamino) como medio de enraizamiento. En la finca experimental "La Lola" del Instituto Interamericano de Ciencias Agrícolas, desde hace algún tiempo, se ha usado para este fin el aserrín de madera. Para conocer cuál de ellos reunía mayores ventajas se proyectó el presente trabajo en que se compara el aserrín de madera con el pergamino del café.

MATERIALES Y METODOS

Este ensayo se llevó a cabo en el Propagador Turrialba No. 3, descrito por Alvim (1), utilizando para cada repetición una caja de madera de 1 m. de largo x 0.90 m. de ancho x 0.15 m. de altura, dividida a la mitad; en una parte se colocó el aserrín y en la otra el pergamino del café, haciéndose la distribución por sorteo. Se utilizaron 12 repeticiones, o sea 12 cajas de propagación.

Ambos materiales eran nuevos y se lavaron bien con agua antes de colocar las estacas. En cada sección de las cajas se colocaron 15 estacas con 4 hojas cada una, provenientes del Clon UF 221. Todas ellas fueron tratadas previamente, en sumersión rápida, con ácido indolbutírico a 8.000 ppm. disuelto en alcohol.

Durante la primera semana se regaron las estacas tres veces al día, y después una vez al día, en las horas de mayor insolación.

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RESULTADOS

Tomados los datos del número de estacas enraizadas, se convirtieron a porcentaje de enraizamiento. El cuadro No. 1 enseña los resultados obtenidos y convertidos a la forma indicada. Se obtuvo un promedio de 66,35 porciento de estacas enraizadas en el pergamino de café contra 51,55 porciento en el aserrín. Esa diferencia ha sido altamente significativa conforme al análisis de varianza resumido en el cuadro No. 2.

CUADRO No. 1

Porcentaje de enraizamiento de estacas de cacao del clon UF 221 en pergamino de café y en aserrín de madera. Finca La Lola, abril 1954

Repeticiones	Porciento de Enraizamiento	
	Pergamino	Aserrín
1	81,25	56,25
2	87,50	68,75
3	87,50	62,50
4	68,75	56,25
5	81,25	62,50
6	56,25	68,75
7	50,00	62,50
8	87,50	43,75
9	68,75	56,25
10	56,25	37,50
11	31,15	12,50
12	40,00	31,10
Sumas	796,25	618,60
Promedio	66,35%	51,55%

F I S I O L O G I A

ALVIM, P. de T. Studies on the cause of cherelle wilt of cacao. 5RTIC/Doc.10 Fisiol/1

MACHICADO, M. and P. de T. ALVIM. Sintomatología de las deficiencias minerales en cacao. 5RTIC/Doc.11 Fisiol/2

STUDIES ON THE CAUSE OF CHERELLE WILT OF CACAO

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The yellowing and subsequent drying of cacao fruits before they have reached the age of about two and a half months is one of the more serious causes of reduction in the yield of cacao. The malady is usually known as "cherelle wilt" and has been reported to cause losses sometimes as high as 60 to 93 per cent in the number of fruits set (10, 19, 23). The cause or causes of the malady are not well understood. Pound (22) suggested that rapid growth of leaf flushing, excessive rainfall and extreme dryness might be factors that induce the wilting of young cacao fruits or "cherelles". Voelcker (26) and Humphries (13) also expressed the opinion that the growth of a new flush results in competition between the developing shoots and growing young fruits and consequently leads to wilting of a greater number of cherelles. According to Humphries (15) this competition is mainly for potassium.

Experiments to control cherelle wilt by means of soil fertilization have been carried out by Cope (4, 5) and Bartolomé (1). The former, working in Trinidad, obtained significant reduction of the malady by means of potassium fertilization; the latter, working in Costa Rica, found no indication as to the possibility of decreasing the incidence of cherelle wilt by means of application of potassium, phosphorus or nitrogen to the soil.

Naundorf and Villamil (19, 20, 21) and Naundorf and Gardner (18) presented data which indicate that cherelle wilt can be controlled by spraying the fruits with some plant growth regulators. Para-chlorophenoxyacetic acid and naphthaleneacetic acid, at concentrations of 25 to 50 ppm were recommended as giving the best results (13). The same treatment was also claimed to increase fruit setting of cacao (7, 8).

This report covers the results of some investigations on cherelle wilt carried on at the Inter-American Cacao Center of the Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica from July 1951 to December 1953. The following studies are discussed: (a) seasonal incidence of cherelle wilt, (b) the influence

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of food supply and (c) the influence of hormone sprays.

MATERIALS AND METHODS

The studies reported in this paper were carried out at the experimental farm La Lola, located in the Atlantic side of Costa Rica, at 24 to 58 meters above sea level. The plants used were about 35 years old (except where otherwise stated), planted from seeds, and grown under natural shade. They were sprayed with Bordeaux mixture every 30 to 45 days.

Records on cherelle wilt incidence were taken every two weeks and the fruits were carefully inspected to determine whether or not the wilting was caused by insect or fungus damage to the peduncle (17). Only wilting apparently induced by physiological causes was recorded.

Trunk growth was measured every two weeks on 15 plants selected at random from the ones used for cherelle wilt studies. These measurements started on February 27, 1952, and the method used was essentially the same as described by Byram and Doolittle (3). Records were taken also on leaf flushes by general observation of the plants in the experimental area. Ratings were: 0, 1, 2, and 3 (negligible, low, medium, and high).

Weather data were obtained from the meteorological station of the farm, which is equipped with rain gauge, higrothermongraph, sunlight recorder and maximum and minimum thermometer. Only rainfall data was available until January 1952. To study correlation of temperature with growth and cherelle wilt a table was prepared giving the number of hours in different temperature classes during each of the two-week intervals used for growth and cherelle wilt recording. This table was prepared from the thermograph chart, following the method suggested by Brown (2). The temperature classes used were: below 20°C, between 20 and 25°C, between 25 and 30°C, and above 30°C.

Some preliminary studies had shown that cherelle wilt could be induced on fruits before the age of approximately two months by removing a ring of bark both above and below the fruit attachment, thus reducing or checking food translocation to the fruits. These results suggested that it might be possible to determine the influence of leaf surface on cherelle wilt development. The following method was used: twenty terminal branches exposed to direct sunlight during part of the day and bearing a single cacao fruit were selected. Five centimeters below the fruit a 1 mm girdle was made on the stem. There were varying numbers of mature healthy leaves

left above the girdle. As healing of the girdle region usually took place in approximately a month and a half, the fruits were observed for six weeks only.

The experiment to study the possibility of controlling cherelle wilt and increasing fruit setting by means of hormone sprays included four treatments applied every 2 weeks: (a) sprayed with para-chlorophenoxyacetic acid at 50 ppm; (b) idem, 20 ppm; (c) sprayed with water; (d) no treatment. Fifteen trees were used per treatment, selected at random from a group of 60 healthy and well developed plants, located in a section of the farm where shade and soil were fairly uniform. All fruits were removed from these trees at the start of the experiment, July 17, 1952. A 5-gallon knapsack sprayer with a 5-foot long spray gun and a fine "Teejet" nozzle was used to apply the material. Both flowers and fruits were sprayed. The wilted cherelles were harvested and counted every two weeks. Starting November 1952, mature fruits were also harvested and counted. The results were analyzed by group comparison.

EXPERIMENTAL RESULTS

Seasonal incidence of cherelle wilt. Table 1 shows the average number of wilted cherelles per tree, average radial growth of trunk, total rainfall, number of hours in temperature classes below 20°C and above 30°C, and observed flushing condition for each of the two-week periods used in the study. Data on cherelle wilt from July 19, 1951, to January 15, 1952, are not presented in the table due to insufficient meteorological data for correlation studies during this period. They are included, however, in Figure 1, which illustrates also the data on trunk growth, rainfall, flushing peaks, and number of hours with temperature higher than 30°C.

The results show a marked variation in cherelle wilt incidence through the year. High incidence usually occurred after a period of heavy flush and when trunk growth decreased or was completely checked. Practically no cherelle wilt was observed when the average radial growth of trunks was about 0.005 inches for the two-week interval. A significant negative correlation was found between trunk growth and cherelle wilt incidence ($r = -0.314$).

The extremely high incidence of cherelle wilt between October 23 and November 5, 1952, coincided with the highest period of rainfall during the two years of observation (20.17 inches in two weeks). Growth in trunk diameter was completely checked during this period. Poor soil aeration following the heavy rains was probably the cause of the check in growth (6, 16).

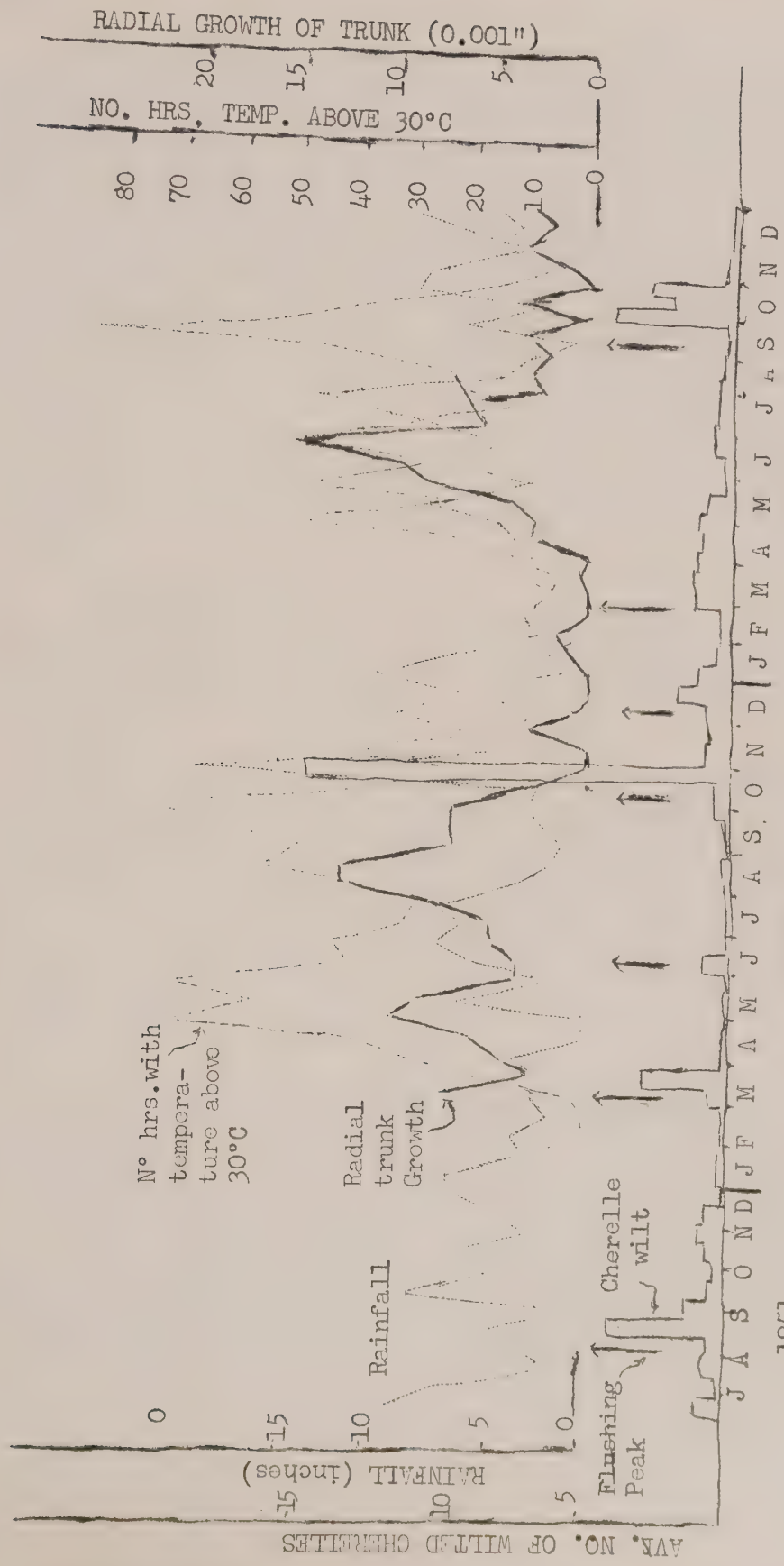

Fig. 1. Cherelle wilt incidence, radial trunk growth, flushing peaks, number of hours with temp. above 30°C, and rainfall, during the 14 days-intervals of study.

No significant correlation was found between cherelle wilt incidence and number of hours of sunlight and number of hours in different temperature classes. Growth in trunk diameter showed a highly significant positive correlation of 0.485 with number of hours with temperature above 30°C. The data show, furthermore, that growth in trunk diameter decreases soon after a flushing takes place. A significant negative correlation of -0.336 was found between flushing intensity and trunk growth two weeks after flushing. This is contrary to Humphries' theory according to which trunk growth increases when flushing takes place (12). The effect of environmental factors on leaf flushing will be considered in another paper, where additional data on this phenomenon will be presented. At this point, it is worth pointing out that, under the conditions where these studies were carried out, flushing does not seem to be caused by increases in air temperature, as postulated by Humphries (11). As the data show, flushing peaks were often observed during periods of relatively low temperatures or soon after.

Influence of leaf surface on cherelle wilt. Table 2 shows the results obtained in the test to determine the effect of leaf surface (number of leaves) on the development of young cacao fruits. A narrow girdle was made below the fruit attachment; the number of leaves above the girdle varied from 3 to 15.

These results demonstrate that cherelle wilt may be caused by inadequate supply of organic substances, probably sugar, from the leaves. Under the conditions prevailing during this test, the minimum number of leaves necessary for the normal development of a young fruit seemed to lie between 7 and 10. This number, however, varies with environmental factors and physiological conditions of the trees. Isolated tests performed with branches under the canopy of the tree, where shade was relatively dense, resulted in wilting of young cherelles above the girdle, sometimes even when the number of leaves was greater than 20.

Influence of hormone spray on cherelle wilt. The results of the experiment to determine the possibility of controlling cherelle wilt and increasing fruit setting by means of sprays with para-chlorophenoxyacetic acid are summarized on Table 3. The analysis of variance showed that the differences both in yield and cherelle wilt incidence were far from being significant. A highly significant positive correlation of 0.595 was found between cherelle wilt and yield of individual plants. Based on this correlation, analysis of covariance was applied to data on cherelle wilt. The results were again far below the level of significance.

Inasmuch as neither yield nor cherelle wilt seemed to have been affected by the treatments, it may be concluded that fruit setting was also not affected.

DISCUSSION AND CONCLUSIONS

The data obtained on seasonal incidence of cherelle wilt corroborates the observation by Pound (22), Voelcker (26), and Humphries (13), according to which higher incidence usually occurs after a period of intensive growth of leaf flushes. The study on the influence of leaf surface on cherelle wilt indicated that the malady can be caused by a deficient food supply (probably carbohydrates) from the leaves. Evidence was also obtained that heavy rains caused severe incidence of wilting, as Pound had observed (22), and also checked growth in trunk diameter. The data also indicated that cherelle wilt incidence was negatively correlated with growth in trunk diameter, being higher when the latter decreased or was checked.

Inasmuch as cherelle wilt seems to be correlated with the growth condition of the plant, its primary cause cannot be regarded apparently as a simple case of nutritional deficiency. In the light of the foregoing investigations, it appears that the malady is caused by food strains brought about either by competition between growing leaf flushes and young fruits or by depression in the mechanism of food translocation. Both the rate and the direction of food translocation are known to be closely correlated with the growing condition of the plant (6). The high incidence of cherelle wilt following heavy rains is very likely a consequence of poor aeration which in turn interferes with water absorption, growth and food translocation in the plant (6, 16). This indicates that good drainage might be an important control measure against cherelle wilt in the region where this study was carried out.

In the present work no indication was found that sprays with para-chlorophenoxyacetic acid, at 20 and 50 ppm, increased fruit setting or decreased cherelle wilt, as work carried out in Colombia seemed to indicate (8, 18). It is possible that differences in plant material was responsible for this discrepancy in experimental results.

In other plants, some type of fruit abscission, such as the one caused by poor flower fertilization and the so-called "preharvest drop" of pears, apples, citrus, etc., have been explained as caused by auxin deficiency and have been successfully controlled by means of sprays with growth regulating substances (25). Other types of fruit abscission, such as the "June drop" of pears, citrus, etc., cannot be controlled by this type of treatment (25). Van Overbeek (25) does not consider the latter as a "true" type of

abscission, i.e., an abscission caused by auxin deficiency. He attributes it to carbohydrates train in the plant and recommends thinning of fruits as a control measure. In the author's opinion, cherelle wilt, as occurring in Costa Rica, is of the same physiological nature of "June drop". This is indicated from the fact that cherelle wilt could be induced by depressing the food supply to young fruits. Furthermore, as studied by Humphries (14), the carbohydrate reserves in the bark and wood of cacao have been shown to decrease when flushing and cherelle wilt occur. Humphries (15) had later postulated that competition for potassium was the main cause of cherelle wilt. This conclusion, however, was based on experiments carried out in Trinidad, where potassium deficiency is of rather common occurrence (9). In Costa Rica, potassium fertilization had apparently no effect in controlling cherelle wilt (1).

In regions where self-incompatibility is a common phenomenon in cacao, poor flower fertilization might be a cause of cherelle wilt and hormone sprays might be expected to help in controlling the malady. According to Sanclemente (24) self-incompatibility seems to be rather common in Colombia (10 to 50% of the plants). The effect of hormone sprays on cherelle wilt and fruit setting, as reported in Colombia (7, 8, 18, 19, 20, 21), could be related to this common occurrence of self-incompatibility. In Costa Rica , self-incompatibility does not appear to be of very common occurrence.

Humphries (12) reported that growth in trunk diameter follows the cycle of leaf flushes and that the latter is caused by increase in air temperature to values above 83°F (28.3°C) in the shade (11). The data obtained in the present work did not support these points of view. Flushing was often observed during periods of relatively low temperature or soon after, and was negatively correlated with growth in trunk diameter. A highly significant positive correlation was found between growth in trunk diameter and the number of hours with temperature above 30°C.

SUMMARY

The results of some investigations on the cause of "cherelle wilt" of cacao (the yellowing and subsequent drying of young fruits) and on the possibility of its control by means of sprays with parachlorophenoxyacetic acid are reported. The data obtained indicated that higher incidences of cherelle wilt usually occur after periods of intensive growth of leaf flushes and/or when growth in trunk diameter decreased or was checked. Heavy rains checked growth in trunk diameter and caused severe incidence of cherelle wilt. The

malady could be induced in terminal branches bearing young fruits by reducing the number of leaves to less than 6-9 per branch, and making a girdling below the fruit attachment. Spraying the fruits with para-chlorophenoxyacetic acid (20 and 50 ppm) did not reduce the malady, as reported from Colombia. Fruit setting also was not affected by this treatment.

In the author's opinion cherelle wilt in Costa Rica appears to be caused by food strains in the plant brought about either by competition between growing leaf flushes and young fruits or by depression in the mechanism of food translocation. The high incidence of cherelle wilt following heavy rains is thought to be a consequence of poor soil aeration which in turn interferes with growth and food translocation in the plant.

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Table 1. Average incidence of cherelle wilt of cacao, average trunk growth, flushing condition, and total hours in different temperature classes for two-week intervals, from January 17, 1952 to December 30, 1953. La Lola Experimental Farm, Costa Rica.

Interval of time	Cherelle wilt (av. 40 trees)	Radial trunk growth (Av. 15 trees) 0.001"	Estimated flushing condition	Total rainfall inch.	Total Number of Hours in Temperature Classes	
					Under 20°C	Above 30°C
1-17/30-52	.20		0	2.90	20.5	8
1-31/2-13	.12		0	3.85	39	0
2-14/27	.10		2	1.52	26	0
2-28/3-12	.60	7.8	3	2.74	47	2
3-13/26	2.87	2.4	1	2.39	13	17
3-27/4-9	.22	4.5	1	3.61	16.5	30.5
4-10/23	.22	6.08	0	0.39	12.5	38.5
4-24/5-7	.05	10.08	0	0.02	9.5	73
5-8/21	.15	8.6	1	6.74	0	57.5
5-22/6-4	.00	3.6	1	1.30	0	71
6-5/18	.80	3.5	2	5.66	0	41
6-19/7-2	.075	4.8	1	7.53	0	44.5
7-3/16	.05	4.9	0	6.14	0	31
7-17/30	.05	7.6	0	7.91	3.5	28.5
7-31/8-13	.10	12.4	0	3.53	7	40
8-14/27	.15	12.7	0	1.56	1	55
8-28/9-10	.025	6.9	1	0.90	0	49.5
9-11/24	.025	6.9	0	2.05	0	59.5
9-25/10-8	.425	6.9	2	2.86	0	74
10-9/22	.475	2.4	2	2.57	0	37.5
10-23/11-5	14.625	0.0	1	20.17	5.5	25
11-6/19	.90	0.0	0	3.35	6	38
11-20/12-3	.75	3.1	0	5.88	19	16
12-4/17	.85	.4	2	9.39	5	7
12-18/31	1.9	0.0	1	6.55	0	18.5
1-1/14-53	1.515	0.0	1	10.91	4	3.5
1-15/28	.575	1.0	0	6.45	26.5	7
1-29/2-11	.30	1.5	0	2.46	13	1
2-12/25	.25	0.0	3	3.18	7	13
2-26/3-11	1.1	0.0	3	1.94	24	3.5
3-12/25	1.15	0.5	1	1.24	16	11
3-26/4-8	1.00	0.0	0	3.27	0	10
4-9/22		3.0	0	3.50	0	22.5
4-23/5-6	1.00	2.5	1	4.23	0	52
5-7/20	.70	4.0	0	8.83	0	24.5
5-21/6-3	.20	8.0	0	2.86	0	51
6-4/17	.20	10.0	1	6.31	0	28
6-18/7-1	.52	15.3	1	4.60	0	49
7-2/15	.52	5.8	1	7,93	0	36.5
7-16/29	.48	6.6	0	4.42	0	13.5
7-30/8-12	.50	2.5	0	13.98	0	22.5
8-13/8-26	.47	2.6	0	4.01	4	24
8-27/9-9	.42	2.2	1	6.60	1	44
9-10/9-23	.37	3.2	3	2.72	1.5	84
9-24/10-7	4.35	0.0	3	0.77	0	55
10-8/10-21	2.23	3.3	2	1.95	10	41
10-22/11-4	3.25	0.0	1	8.10	7	19.5
11-5/11-18	.32	1.0	0	7.99	29	6.5
11-19/12-2	.08	2.6	0	2.77	16	17
12-3/12-16	.10	1.5	0	5.55	18.5	13.5

Table 2. Cherelle wilt of cacao on girdled terminal branches of cacao as affected by the number of leaves present. La Lola Farm, Costa Rica. 1951.

Number of Branches	Number of leaves left on branch	Initial Volume of fruits (cm^3) July 7	Observations		
			July 19	August 3	August 16
1	3	5	Cherelle wilt		
2	3	6	Cherelle wilt		
3	3	18	Cherelle wilt		
4	3	15	Cherelle wilt		
5	5	26	Normal	Cherelle wilt	
6	5	13	Cherelle wilt		
7	5	17	Normal	Cherelle wilt	
8	5	5	Cherelle wilt		
9	6	3	Cherelle wilt		
10	9	7	Normal	Normal	Normal
11	10	11	Normal	Normal	Normal
12	10	13	Normal	Normal	Normal
13	10	8	Cherelle wilt		
14	10	30	Normal	Normal	Normal
15	12	21	Normal	Cherelle wilt[a]	
16	15	11	Normal	Normal	Normal
17	15	.	Normal	Normal	Normal
18	15	9	Normal	Normal	Normal
19	15	27	Normal	--b	
20	15	13	Normal	Normal	Normal

a/ Leaves relatively small and with some holes.
b/ Branch broken.

Table 3. Yield (number of harvested mature fruits) and wilted cherelles per tree, from July 1952 to December 1953 (average of 15 trees)[a]. La Lola Farm, Costa Rica

Treatment	Yield	Cherelle Wilt	
		Average Number	Percent As of Yield
Sprayed with para-chlorophenoxy-acetic acid, 50 ppm	106,8	41.1	38.3
Sprayed with para-chlorophenoxy-acetic acid, 20 ppm	110,3	57.4	51.9
Sprayed with water	109,4	46.7	42.7
No treatment	107,6	52.5	48.8

a/ None of the yield or cherelle wilt differences are statistically significant at the 5 per cent level.

SINTOMATOLOGIA DE LAS DEFICIENCIAS MINERALES EN CACAO*

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El conocimiento de los síntomas visuales que presentan las plantas cuando hay carencia de elementos minerales, trae valiosa ayuda práctica en el problema de abonamiento o corrección de las deficiencias nutricionales del suelo. Maskell, Evans y Murray (5), del Colegio Imperial de Agricultura Tropical de Trinidad, han publicado recientemente los resultados de sus experimentos sobre el cultivo de cacao en soluciones nutritivas y en arena, en el cual describen los síntomas de deficiencia de todos los elementos minerales hasta ahora reconocidos como esenciales para las plantas. Algunos de los síntomas de la deficiencia de nitrógeno, fósforo y potasio ya habían sido anteriormente establecidos por McDonald (6) en 1934. Greenwood y Hayfron (2) en 1951, describieron también los síntomas de deficiencia de zinc y hierro en cacao.

En abril de 1953, cuando todavía no se había publicado el informe final de Maskell, Evans y Murray (5), aparecido en septiembre de 1953, se inició en el Instituto Interamericano de Ciencias Agrícolas, un experimento para reproducir en cultivos de arena, los síntomas de deficiencias minerales en cacao, para todos los elementos considerados esenciales, a excepción del molibdeno. Los resultados se obtuvieron entre octubre de 1953 y febrero de 1954. De modo general se confirmó la mayoría de las conclusiones de Maskell, Evans y Murray, pero también se obtuvieron algunas informaciones adicionales y unos pocos resultados en desacuerdo con las observaciones de los citados autores, principalmente respecto a los síntomas de deficiencia de magnesio y de calcio. Por el gran interés práctico del asunto y reconociendo la necesidad de definir lo más claramente posible los síntomas de deficiencias minerales en cacao, los autores consideran oportuna la divulgación de los resultados obtenidos.

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* La mayor parte de los resultados de este trabajo se incluyó en la tesis titulada "Diagnóstico de deficiencias minerales en cacao por síntomas visuales, ensayos en invernadero e inyecciones en el tronco", presentada por M. Machicado al Consejo de Estudios Graduados del Instituto Interamericano de Ciencias Agrícolas, para la obtención del grado de Magistri Agriculturae.

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MATERIALES Y METODOS

El cultivo en arena se hizo en un invernadero de techo de material plástico (Resolite), de color verde, que deja pasar alrededor de 35% de la intensidad de la luz solar. Se utilizaron macetas de porcelana de 25 cm. de alto por 20 cm. de ancho, con una capacidad de 8 litros. Estas macetas tenían un orificio lateral de 1,5 cm. de diámetro situado en la parte de abajo, al nivel del fondo, para el drenaje. La arena fué adquirida en una fábrica de porcelana en San José, Costa Rica, y se obtuvo por trituración de roca cuarzosa calcinada. Los fragmentos medían de 1 a 3 mm. de diámetro y fueron separados por medio de zarandas. La solución nutritiva usada ha sido la de Hoagland y Arnon (4), haciéndose las substituciones necesarias para el estudio de las deficiencias. Para preparar las soluciones se empleó solamente agua de lluvia, la cual era colectada en el propio techo del invernadero, y llevada por medio de un canal, también de material plástico, a un tambor de hierro galvanizado de 200 galones, pintado por dentro con pintura de asfalto. Se aplicaron dos litros de solución por maceta, los cuales se infiltraban rápidamente y quedaban en el fondo, saturando la arena hasta la altura de más o menos 1/3 de la maceta. Para facilitar la aeración, se drenaba diariamente todas las macetas entre las 5 y 6 horas de la tarde, y a la mañana siguiente se volvían a poner las soluciones por arriba. Este sistema dió resultados muy satisfactorios respecto al crecimiento de las plantas, pero después del segundo mes se observaron acentuados síntomas de deficiencia de hierro en las plantas de todas las macetas, con excepción hecha de las que fueron tratadas sin fósforo. Se introdujo entonces una modificación en la solución nutritiva: se utilizó "quelado de hierro" (iron chelate), 0,2 g por litro, en sustitución del tartatro de hierro recomendado por Hoagland y Arnon (4). Esta modificación remedió perfectamente la deficiencia de hierro en menos de 2 semanas, y no se observaron más anormalidades en las plantas.

Los tratamientos empleados fueron los siguientes: a) solución completa; b) solución sin nitrógeno; c) sin fósforo; d) sin potasio; e) sin magnesio; f) sin calcio; g) sin azufre; h) sin hierro; i) sin manganeso; j) sin boro; k) sin zinc; l) sin cobre.

Todas las plantas que se usaron en el estudio pertenecían al clon U.F. 613 . Se prepararon tres macetas por tratamiento, cada una con tres plantas, haciendo así un total de nueve plantas por tratamiento. De esas nueve plantas, cuatro provenían de estacas de una sola hoja y cinco de semillas de un mismo árbol. Las semillas fueron puestas a germinar en arena y se les quitaron los cotiledones después de que se formaron las primeras hojas. Las plántulas fueron trasplantadas a las macetas cuando tenían unos 45 días de edad.

DESCRIPCION DE LOS SINTOMAS DE DEFICIENCIA

Nitrógeno

Las características de la deficiencia de nitrógeno se hicieron más perceptibles en las plantas provenientes de semilla. En las primeras semanas se pudo apreciar un crecimiento retardado que se hizo más notorio con el transcurso del tiempo. También se apreció una reducción del tamaño de la lámina y del número de hojas. Este síntoma fué más visible en las nuevas brotaciones, en las cuales sólo 2 a 3 hojas llegaron a desarrollarse.

La característica más típica de esta deficiencia se encontró en la reducción del tamaño y en el color verde pálido de todas las hojas. (Fig. 1, 2). Al principio se notó una ligera clorosis que luego se tornó más intensa. A medida que la deficiencia se hizo más aguda, la parte apical de las hojas más viejas presentó necrosis, la cual alcanzó hasta la mitad de la lámina (Fig. 3), provocando así la caída de la hoja.

En plantas propagadas vegetativamente, el desarrollo de las primeras yemas fué muy lento y muchas de ellas no desarrollaron. Los síntomas de nitrógeno en las hojas fueron visibles, pero en hojas jóvenes, estos síntomas podían confundirse con los otros elementos. Antes de que las hojas alcanzaran una completa maduración, se produjo una defoliación; las estacas, sin embargo, no consiguieron una nueva brotación y murieron en un tiempo relativamente corto.

Fósforo

Las plantas, en las primeras semanas de crecimiento, aparentemente no presentaron ningún síntoma. Las yemas se desarrollaron normalmente y las hojas de la primera brotación alcanzaron un tamaño semejante al de las plantas sometidas a un tratamiento completo. El número de las hojas de las subsiguientes brotaciones fué normal, pero la lámina sufrió una reducción más pronunciada en el ancho que en el largo, con respecto al tamaño normal (Fig.4).

Al principio las hojas conservaron su color verde normal, pero cuando la deficiencia fué más severa, las hojas más viejas se tornaron claras con una pigmentación rojiza por lo general más notoria en la parte apical. Más tarde se inició una defoliación comenzando en la base del tallo (Fig. 2), permaneciendo las estípulas, las cuales resaltaron por su color verde. En las plantas propagadas vegetativamente este síntoma fué más perceptible. No se observó gran reducción en el tamaño de las plantas.

Potasio

Las plantas cultivadas sin potasio mostraron en su primera edad un desarrollo normal; poco tiempo después se pudo apreciar un crecimiento retardado.

A los seis meses las hojas más viejas empezaron a manifestar una clorosis que se inició por el ápice y se extendió hacia los contornos de la lámina; este síntoma permaneció por algo más de una semana. Las zonas cloróticas se transformaron en zonas necróticas, que cubrieron la mitad de la lámina (Fig. 2 y 5). Relativamente hubo poca defoliación.

Cuando las hojas de la base se encontraban en un estado necrótico, las que estaban por encima de éstas comenzaron a desarrollar clorosis, conservando las brotaciones superiores sus características normales. De esta manera se pudieron apreciar, dentro de una misma planta, las tres fases de desarrollo de la deficiencia: forma avanzada, forma intermedia y forma incipiente (Fig. 2).

Una característica que resaltó en el caso de esta deficiencia, fué la aparición de un estado clorótico en toda la lámina de las hojas de la región apical que es comparable con el síntoma de falta de hierro. Esto se debe a que la deficiencia de potasio dificulta la mobilización del hierro, causando la aparición de este síntoma (3).

La carencia de este elemento mineral ha sido observada en condiciones de campo en la región atlántica de Costa Rica, en las proximidades de la ciudad de Limón (Fig. 6).

Magnesio

Las primeras manifestaciones de deficiencia de magnesio empezaron en las hojas más viejas. En la región intervenal se pudo observar una clorosis muy ligera, acompañada por pequeñas manchas que muy pronto comenzaron a extenderse hasta constituirse en una necrosis intensa. Esta necrosis, sin embargo, no alcanzó la región nerval, el ápice o bordes de la lámina (Fig. 7).

Los síntomas de la deficiencia de magnesio no pudieron observarse en las plantas propagadas vegetativamente, pues todas las estacas destinadas a la observación murieron antes de que presentaran síntomas de esta deficiencia.

Cumple notar que Maskell, Evans y Murray (5), trabajando con plantas provenientes de estacas, describieron síntomas de deficiencia

de magnesio muy distintos de los encontrados en este trabajo. Ellos encontraron clorosis seguida de necrosis en la parte marginal de la hoja, y por las fotografías publicadas esos síntomas son muy parecidos a los de la deficiencia de potasio.

Boynton y Erickson (1) encontraron en los viveros de cacao, en Turrialba, síntomas análogos a los obtenidos en este trabajo en las plantas sin magnesio, y consiguieron curar la deficiencia por medio de la fertilización con sulfato de magnesio.

Calcio

También en la deficiencia de calcio se obtuvieron síntomas muy distintos a los descritos por Maskell, Evans y Murray (5), para plantas provenientes de estacas.

La planta de cacao parece ser extremadamente sensible a la falta de calcio. Desde un principio las plantas mostraron síntomas severos. Las estacas sólo lograron alcanzar la primera brotación y murieron en poco tiempo. En cambio, cuando se usaron plantas de semilla, desde muy temprano se pudo observar un desarrollo retardado. Las pocas hojas que aparecieron eran muy pequeñas y débiles. En vista de tal circunstancia, estas plantas fueron tratadas con una solución completa. Las plantas reaccionaron en poco tiempo y en las próximas brotaciones adquirieron caracteres normales.

Al final de la tercera brotación el calcio fué nuevamente eliminado de la solución y las plantas mostraron otra vez síntomas de deficiencia; al poco tiempo se fué paralizando el crecimiento y las hojas más nuevas empezaron a presentar áreas necróticas que se iniciaron en las partes intervenales en forma de manchas localizadas especialmente en la base de la lámina y muy cerca de la nervadura central (Fig. 8). En general la necrosis empezaba muy antes de que la hoja, llegara a su plena maduración.

A medida que la deficiencia se hizo más crítica, la necrosis alcanzó la nervadura principal y las secundarias. Los márgenes de la lámina, al igual que el ápice, no mostraron necrosis, presentando únicamente un agotamiento que dió a los bordes una ondulación contínua. Este estado fué seguido de la abcisión de las hojas afectadas.

Azufre

El tamaño de las plantas cultivadas sin azufre aparentemente fué normal durante los cuatro primeros meses. A partir de esta

edad el desarrollo se hizo más lento, y se empezó a observar un empalidecimiento general de las hojas (Fig. 9), principalmente de las más viejas. No hubo reducción pronunciada en el tamaño de las hojas como en el caso de la deficiencia de nitrógeno. La clorosis se distribuyó uniformemente portoda la superficie de la hoja incluyendo también las nervaduras. Hubo relativamente poca defoliación.

Cuando la deficiencia se hizo más aguda, los bordes y el ápice presentaron una necrosis que alcanzó hacia el centro de la lámina, siendo las nervaduras las partes más fácilmente afectadas.

Hierro

Las primeras manifestaciones de la falta de hierro empezaron en las plantas propagadas vegetativamente y poco tiempo después en las plantas de semilla. En ambos casos, las plantas presentaron clorosis más pronunciada en las hojas nuevas. A las pocas semanas esta clorosis se tornó más intensa, las hojas apicales presentaron un color casi blanco con excepción de las nervaduras, que conservaron su color verde (Fig. 10 y 11). Prácticamente no hubo reducción en el tamaño de las hojas afectadas.

A medida que la deficiencia tomó caracteres más pronunciados, en las hojas de la segunda brotación se presentaron también síntomas bien característicos; de esta manera dentro de una misma planta fueron perceptibles todos los rangos de deficiencia causados por la carencia de este elemento.

Un ligero agotamiento marginal o apical antecede a la caída de la hoja.

Cobre

En el caso del cobre, las manifestaciones morfológicas no se presentaron claramente en las plantas provenientes de semilla. Posiblemente esto se deba a que los cotiledones pueden suplir cierta cantidad de cobre.

En algunas de las plantas propagadas vegetativamente, los síntomas se manifestaron en las primeras brotaciones, mientras que en otras plantas los síntomas fueron visibles a partir de la segunda brotación.

Los síntomas se presentaron en las hojas más nuevas, las cuales se redujeron mucho en tamaño. La característica más sobresaliente se presentó en las nervaduras secundarias. Como ya habían descrito Maskell, Evans y Murray (5) el número de éstas se reduce y las distancias a las que se encuentran no son uniformes. En la

región basal de la lámina, el área intervenal es muy grande, siendo lo contrario en el ápice, donde las nervaduras se encuentran a muy poca distancia (Fig.12). La región apical de la hoja parece ser la más susceptible a la falta de cobre, pues muy rápidamente y sin pasar por un estado clorótico, se desarrolla una necrosis.

Manganeso

Los síntomas han sido más fácilmente observados en las plantas propagadas vegetativamente. Las partes más afectadas fueron hojas jóvenes, las que a un principio conservan su color verde normal y muy pronto comienza la aparición de pequeñas áreas cloroticas que se inician por la parte apical de la lámina, abarcando las regiones intervenales (Fig. 13).

Las nervaduras y las áreas contiguas a éstas, mantienen su color verde normal; esto se puede apreciar en la nervadura principal, en las secundarias y aún en las terciarias.

A medida que la deficiencia se hace más intensa, la zona clorótica del ápice pasa a un estado necrótico que no logra alcanzar una gran área debido a la rápida caída de la hoja.

En el caso de las plantas provenientes de semilla, los síntomas fueron los mismos que los descritos, pero su aparición fué más retardada.

Boro

En las plantas propagadas vegetativamente, se notó un desarrollo retardado; se pudo apreciar claramente que las partes afectadas fueron los puntos de crecimiento, pues las partes terminales presentaron deformaciones (Fig. 14).

En las plantas provenientes de semilla, los síntomas foliares fueron muy evidentes. En las hojas más jóvenes, se observó una deformación, un arrollamiento de la lámina en forma de espiral y un volteamiento de los ápices hacia atrás (Fig. 15).

En general, las hojas afectadas se presentaron más gruesas y duras al tacto.

No se observó clorosis y abcisión de las hojas terminales, síntomas encontrados por Maskell, Evans y Murray, pero aparentemente asociadas a deficiencias muy severas o a la completa ausencia de boro en la solución.

Zinc

No se pudieron obtener los síntomas típicos de la deficiencia de zinc, descritos por Greenwood y Hayfron (2) y confirmados por Maskell, Evans y Murray (5). Según los citados autores ésta deficiencia se manifiesta principalmente en las hojas nuevas, las que se tornan angostas, frecuentemente curvadas en forma de hoz y se ponen muy pálidas o de color blanco crema. Bajo las condiciones experimentales utilizadas en el presente estudio, aparentemente hubo contaminación del agua en el tambor de hierro galvanizado usado como colector, o las sales empleadas contenían zinc como impureza en cantidad suficiente para suplir las necesidades de la planta.

CONCLUSIONES

Los resultados de este estudio confirman en su mayor parte las descripciones de Maskell, Evans y Murray (5) para los síntomas de deficiencia de nitrógeno, fósforo, potasio, azufre, hierro, manganeso, boro y cobre, pero señalan una pronunciada diferencia en los síntomas de deficiencia de magnesio y calcio. Los citados autores han señalado una necrosis marginal en las hojas más viejas como síntomas típicos de deficiencia de magnesio en cacao. Para la carencia de calcio, señalaron puntos cloróticos en las hojas nuevas y severa necrosis marginal en las hojas viejas, "sin formación de islas necróticas en el centro de la lámina". En el presente trabajo no se obtuvo ninguno de estos síntomas. Se obtuvo formación de islas necróticas en el medio de la lámina, en ambas deficiencias. Estos síntomas se han marcado bien en todas las repeticiones. En la falta de calcio los síntomas aparecen en las hojas nuevas, aún antes de su completa expansión; en la falta de magnesio ellos solamente aparecen en las hojas más viejas. Las áreas necróticas en la deficiencia de calcio se forman bien cerca de la nervadura principal, y se desarrollan rápidamente, provocando la absición antes de la completa maduración de las hojas. En la falta de magnesio la necrosis empieza por puntos que se van alargando y uniendo hasta la formación de áreas más grandes; sin embargo, no se aproximan tanto a la nervadura principal como en la deficiencia de calcio, y las hojas afectadas permanecen en la planta por un espacio de tiempo relativamente largo. En ambas deficiencias la necrosis es relativamente más severa en la mitad basal de la hoja.

Debe señalarse que Markell, Evans y Murray (5) han utilizado en su trabajo solamente plantas provenientes de estacas enraizadas. En el presente trabajo los síntomas de deficiencia de magnesio y de calcio se obtuvieron en plantas provenientes de semilla, pues las propagadas vegetativamente que se sometieron a dichos tratamientos se perdieron. Se puede suponer que esa diferencia en el

material utilizado es responsable de las diferencias obtenidas en los síntomas, pero esa hipótesis no se puede aclarar sin futuras investigaciones.

Confirmando los resultados de este estudio respecto a los síntomas de deficiencia de magnesio, se debe señalar que síntomas semejantes han sido observados en condiciones de campo por Boynton y Erickson (1), también en plantas provenientes de semilla, y que la anormalidad se ha corregido con la aplicación de sulfato de magnesio; además, los análisis de suelo y de las hojas, hechos por los citados autores dieron incuestionable evidencia de que se trataba de una deficiencia de magnesio.

SUMMARY

Young cacao plants, both from seeds and rooted cuttings, were cultivated in quarts sand treated with nutrient solutions of different compositions, in order to reproduce the typical symptoms of various mineral deficiencies. Deficiency symptoms of the following elements are described and illustrated with pictures: nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, manganese, boron, and copper. Symptoms of calcium and magnesium deficiency obtained in this work do not correspond to the ones described by Maskell, Evans and Murray (5) for the same elements. Deficiency symptoms of the other elements agree in general with the descriptions given by the above authors.

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CONTRIBUTION TO THE STUDY OF SURVIVAL, DISSEMINATION AND CONTROL OF PHYTOPHTHORA OF CACAO

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To obtain effective control of Phytophthora palmivora of cacao two of the factors which must be considered are the survival and dissemination of the causal organism. McRae (7) found that P.palmivora of Hevea brasiliensis exists during the dry season as mycelium on living and dead tissue on branches that partially died back. He observed living mycelium at the insertion of the stalk on fruits that have been infected at the onset of the wet season when rain falling through the leaves spread infection from dead branches to the new growth and to the fruit, leaves and eventually to the panels.

The survival value of this fungus when attacking Hevea was studied also by Darley and Silverborg (5). They found that when leaves with pieces of young stem were inoculated and buried one to two cm deep in the soil, the fungus was still viable on the plant material at the end of 60 days which indicated that resting spores produced in the tissue of fallen leaves might also carry fungus through the dry periods, or that the fungus survives for some time on plant parts buried in the soil. Differences in survival may very likely exist between the strains of P.palmivora that attack cacao and that attack rubber. Preliminary studies at the Inter-American Institute of Agricultural Sciences show that these two strains are not similarly pathogenic as determined by reciprocal inoculations on these two hosts. Also when grown in the same artificial media these two strains differ in growth appearance.

Some evidence of the dissemination of spores of P.palmivora of cacao has been presented by Thorold (17/18) from studies conducted in Nigeria. The role of insects as disease vectors or the effect of their wounding on infection to cacao has not been inves-

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tigated in detail. The distribution of the fungus on cacao and other hosts other than cacao was summarized in 1946 by Bougnicourt (2).

SURVIVAL

The survival value of P.palmivora in the soil and in cacao shell dump piles was investigated by four methods in the laboratory of the Inter-American Institute of Agricultural Sciences, Turrialba and at its Cacao Experimental Farm "La Lola", Madre de Dios, Costa Rica. These methods were as follows: by inoculating sterile and non-sterile soil with conidia of the fungus; by burying healthy pods in the soil of the cacao plantation; by inoculating pods with suspensions of soil from the cacao plantation; and by burying healthy pods within cacao shell dump piles.

Survival in the soil. Moistened sterile and non-sterile soils in Petri plates were inoculated with an aqueous suspension of conidia of P.palmivora # 21, isolated from cacao. When surface-desinfected, healthy shell pod pieces, epidermis down, were placed in direct contact with these soils every 15 days until infected, it was found that the shell pieces in both soil series developed Phytophthora infection while the non-sterile soil yielded also a few isolations of Pythium, Fusarium and common saprophytes. However, infection developed on the shell pieces after 24 hours in the sterile soils, whereas in the non-sterile soils infection did not appear before 72 hours. The pieces were completely rotted in four to five days and were removed from the soil. The amount of infection expressed as brown discoloration showed that the Phytophthora fungus was alive in both soils for as long as 101 days under the conditions of the experiment. From the shell pieces infected the fungus was reisolated and inoculated successfully back to cacao pods. This demonstrates that P.palmovora is able to survive in the absence of cacao host tissue.

In another experiment, whole, healthy, surface-disinfected cacao were buried in holes in the plantation ground at depths of 0.1 m, 0.5 m, and 1.0 m. The pods, ten for each depth, were buried for 24 hrs., 4, 8 and 12 days. The result were, however, obscure because the holes became filled with underground water and the pods underwent a bacterial rot. However, the pods buried for as long as four days and at depths of 0.1 and 0.5 m had on them spores of P.palmivora. The method of placing a loop-full of suspension of the soil, taken at 0.1, 0.5 and 1.0 m depth levels in the plantation, over the disinfected surface of non-wounded pods was also used. The pods thus treated in large wooden moist boxes were then covered and allowed to incubate. All of the inoculated pods developed marron-brown lesions as well as dark-brown ones, the former

being due to Phytophthora while Fusarium and other saprophytes were mainly responsible for the latter. The areas of these discolorations were larger on pods inoculated with the soil from the upper depth level. None of the checks developed infection.

Survival in cacao shell dump piles. The pH of the discarded cacao shell material used for pod burial was determined colorimetrically to be 7.5 ± 0.2. From laboratory experiments it was found that P.palmivora of cacao grows very well at this acidity and also as low as pH 4.5.

Healthy, non-wounded and surface-disinfected pods were buried at three levels in a cacao shell dump pile under natural conditions. The surface of the pile was leveled previously. The pods were then buried just below the surface pile, at 0.5 and at 1.0 m deep. After 24 hrs., 4, 8 and 12 days the pods were unburied, washed and incubated in moist chambers for 24-48 hrs.

Isolations made from these pods (Table 1) showed that on the average only Phytophthora developed after one to four days of burial in all cases except the fourth day at the 1.0 m depth. After four days other saprophytes and bacteria appeared. At the eighth and twelfth days, except for the 1.0 m depth at the eighth day, in some cases no Phytophthora could be isolated. Except for the first day of burial, the rotting was more severe close to the surface. Surface-disinfected check pods incubated in moist chambers remained healthy.

TABLE 1

Infection of pods buried at three depths in a cacao shell dump pile

Depth in m.	Days of burial			
	1	4	8	12
	Infection type * (Ave. of 10 pods)			
0.1	1.1	3.5	4.4	4.9
0.5	2.1	2.5	4.1	4.3
1.0	1.7	2.1	3.6	4.3

* 0, no infection; 1, 2 and 3, slight, medium and severe infection caused by Phytophthora; 4, severe infection of Phytophthora and presence of saprophytes; and 5, bacterial rot and miscellaneous saprophytes only.

DISSEMINATION

Stakman and Christensen (16) stated that many of the fungi which cause plant diseases depend almost exclusively on the wind for dispersal of their spores. Most of these spores are exceedingly buoyant and may be caught up by even minor convection currents and quickly carried to heights of several miles. Spores have been trapped as high as 36,000 feet by Meier (8/9). Spores fall at a rate measured in millimeters per minute in still air, the rate being faster under humid conditions, according to Stakman's and Christensen's reference (16) to the works of Buller, Christensen, J.J., McCubbin and Ukkelberg. Stakman and Christensen differentiate mere distribution of spores from effective distribution, which "depends upon viable spores being carried to a suitable infection court of a susceptible plant at the proper stage of development and under conditions which will permit infection."

In a reference (16) to the works of Alcock and McIntosh, De Bary, Jensen, Melhus, and Murphy circumstantial evidence has indicated wind dissemination of zoosporangia of P.infestans. Bonde and Schultz (1) found evidence that a common source of late blight infection was the refuse piles of potatoes. The fungus was observed to sporulate freely on sprouts from infected tubers in these piles. Conidia of the fungus were caught on slides 1,000 feet away. The disease was observed to spread 600 feet from such piles, always in the same direction as the wind.

According to Salazar (14) the principal agent involved in the dissemination of sporangia of P.palmivora of cacao is water either as drops, splash or when running on the trees. Wind without rain is not a factor of spore dissemination, but when these two factors act together, wind may become important. Sporangia without rain do not germinate. When sporangia were exposed to a dry atmosphere for as little as five minutes and then submitted to an atmosphere of 82 per cent relative humidity, they were unable to germinate.

Thorold (17) found that this fungus is mainly dispersed by the asexual sporangia. By exposing vaselined discs of cellophane 3 mm in diameter over infected pods he (18) was able to capture sporangia when free moisture was apparently absent during the exposure period. Thus he confirmed the statement of Ashby that mature sporangia of P.palmivora fall away by natural abscission. Thorold showed also that there occurs horizontal dispersal of P.palmivora such as would be expected from an airborne disease (17/18). This investigator studied the dissemination of P.palmivora from a pile of diseased pods to pods on surrounding trees. The percentage of pod rot was found to decrease as the distance from the pile increased, although the decrease was less than would be expected if

the central heap were the only source of infection. He mentioned the possibility of infection from the ground and crop debris and stated that Wright has shown that the fungus can exist saprophytically in the soil. Thorold also says there is evidence for vertical spread to healthy pods from diseased pods several feet below and there is a probability that sporangia may also be dispersed from infected pods in rain splash droplets.

In view of all existing evidence it appears that perhaps the sporangia of P.palmivora of cacao are carried by the wind and may spread infections for distances as yet undetermined under suitable environmental conditions. Factors which may limit the spread of the disease to short distances are the reported shortness of viability of the sporangia and their more rapid precipitation from the air when the relative humidity is high, as is the case in most cacao plantations.

Basically the same experimental design used to study survival was used to make a preliminary study of spore dissemination at "La Lola" plantation. Three series of healthy, surface-disinfected and non-wounded pods were hung from thin cane-supports over the same cacao shell dump pile (Fig. 1). The heights at which the pods were suspended were: just over the surface of the pile, 0.5 m high and 1.0 m high (Fig. 2).

TABLE 2

Infection of pods hung at three heights upon a cacao shell dump pile

Height in m.	Days of exposure			
	1	4	8	12
	Infection type * (Ave.of 10 pods)			
0.0	1.2	2.1	3.3	4.3
0.5	0.5	0.9	2.0	4.5
1.0	0.1	0.9	1.5	4.2

* 0, no infection; 1, 2, 3, and 4, slight, medium, severe and very severe infection caused by Phytophthora only; 5, very severe infection caused by Phytophthora and saprophytes.

The results included in Table 2 show that after 24 hrs. all the pods at 0.0 level had developed an incipient infection. From the original data five out of ten pods at 0.5 m were infected, and only one out of ten exposed at the highest level showed a very slight discoloration. After 12 days of exposure, however, all pods at the three levels became infected and only slight differences in disease severity were observed. Occasionally slight Colletotrichum pod rot was seen on the pods exposed for the longest time. In most cases the majority of the infected area of the pods occurred on the lower half of the pods. Infection of the peduncles or of the upper part was seldom observed (Fig. 2). Evidently sporangia were carried up into the air from the shell dump pile during the non-rainy part of the day by air currents. In the experiment these spores apparently adhere to the suspended pods. During the 12 days of the experiment rain was recorded every day except two days. However, the maximum daily relative humidity was 100 per cent or nearly so. The rain therefore, have washed most of the spores down to the sides and lower halves of the pods where, even for some time after cessation of rain, moist conditions would prevail. It has been shown (13) that on pods inoculated and incubated at 100 per cent relative humidity Phytophthora spores formed appressorial structures and hyphae after three hours. Under the "La Lola" weather conditions * during the experiment the spores had ample moisture and time to germinate and induce infection. Those pods just above the surface of the dump pile could also have been inoculated by rain splash containing spores.

CONTROL

Control of Phytophthora pod rot of cacao can be achieved by sanitation, fungicidal treatment and by the use of disease resistant varieties. The role of insects, the effect, if any, of soil fertilizers and the possible influence of mineral uptake by the leaves on disease development are not clear at this time. Only sanitation and fungicidal control are discussed here. Resistance of cacao to P.palmivora is a subject of separate study,

Sanitation. It must be recognized "a priori" that clean cultivation should reduce the amount of inoculum and curve the inoculum potential as a source of infection and re-infection. Neverthe-

* During the 12 days of the experiment the weather records were as follows: Total rain in 12 days was 4.9 in. with a daily average of 0.41 in.; the other daily averages were: temperature, 25.1°C; maximum relative humidity, 99.7 per cent; minimum relative humidity, 64.3 per cent; sun-hours, 3.34.

less, successful disease control by sanitation must be based on a thorough knowledge of the pathogen's life history, that is--its method of dispersal, its capabilities for survival and its potentialities as a pathogen under known environmental conditions. The pathogen-host relationships, therefore, must be recognized.

According to Thorold (17) sporangia of P.palmivora of cacao are first formed during the night following the second day of visible symptoms. Therefore, by removing affected pods before sporangia are produced every day or every other day, inoculum available for infection could be curtailed. This would require a daily inspection of the pods in the trees. He believes that this method of control is best adapted to the low yielding trees (less than 12 pods per tree) or when the disease is not severe. In the light of the evidence presented by Orellana (13) that the fungus can sporulate within the exocarp of the living cacao pods, the removal of diseased fruits might reduce infection even if sporangia were not present on the pod's surface. Removal of all infected pods may be, however, uneconomical since mature infected pods, if picked before the discoloration has penetrated to the beans, can still be utilized.

Since the fungus remains viable in the cacao shell dump pile, as already shown, these piles should be disposed of, preferably by burning. When more information is obtained on the host range of this organism, recommendations for the elimination of other plants as sources of infection or alternate hosts could be made.

Fungicidal control. In some countries of the Western Hemisphere as well as in some regions of Africa investigations are in progress for the control of Phytophthora rot of cacao with fungicides. In the search for effective fungicides some have been found which give good results for a short time, but are quickly washed away by the weathering action of the tropical rain forest. Efforts thus far have failed to find a good adhesive or alternative method to prolong the action of the fungicide.

Fungicidal spray was started at "La Lola" Cacao Experimental Farm in 1950. The fungicidal material is applied only to the foliage, not directly to the trunk. However, part of the material drips down over the entire tree as well as on the ground where it may have some effect on Phytophthora undergoing a saprophytic stage in the soil and plantation litter. Results of this method of control from 1950 to the present are summarized by Siller (15).

A new fungicidal comparison experiment is in progress at the same farm (12) using Phygon XL Fungidal Powder, Perenox, Crag 531

and Bordeaus mixture at intervals of 30 days. The separate effect of each fungicide cannot yet be given.

Based on the results of a study on infection of cacao by P.palmivora (11/12/13) an experiment is in progress at "La Lola" which has as its main objective to synchronize, if possible, spray applications with periods in which the disease is more destructive. Results of this experiment will be released when enough data are gathered. Thorold (17) in relation to the frequency of fungicidal applications for control of "Black pod" (Phytophthora rot of cacao) stated that this is probably dependent on the extent to which control measures are practiced. He gives as an example the fact that four applications per season are sufficient to control the disease in Fernando Po, where almost all the plantations are sprayed with Bordeaux mixture; and have been for several years.

In Colombia Naundorf (10), studying the effect of copper fungicides on cacao pollination, fertilization and fruit setting, reported that these compounds possess a deleterious effect on these functions. Copper, according to him, inhibits pollen germination and suppresses normal development of the pollen tube. Bridgland (3) however, found in New Guinea that pollination is not an important factor in limiting yield. Cabrera (4), in view of the results obtained by Naundorf, recommends that fungicides containing copper could be used on cacao provided they are added with plant hormones and calcium glycerophosphates, compounds that ameliorate the toxic effect of copper.

The fact that copper inhibits normal fertilization on cacao does not as yet exclude, however, the use of copper fungicides. The increases brought about by copper fungicides in Costa Rica appear to counteract the detrimental effects.

SUMMARY

It was found that surface-disinfected healthy shell pod pieces, when placed every 15 days for 4 or 5 days, epidermis down in direct contact with sterile and non-sterile soils inoculated with Phytophthora palmivora # 21, still became infected 101 days later. Surface-disinfected, non-wounded, healthy pods inoculated with plantation soil from 0.1, 0.5 and 1.0 m depth levels all developed Phytophthora infection after incubation in moist chambers, while the ckecks remained healthy. Infection was more severe on pods inoculated with soil from the shallowest depth. All surface-disinfected, non-wounded, healthy pods buried at depths of 0.1, 0.5 and 1.0 m in a cacao shell dump pile developed Phytophthora rot after 1 to 4

days of burial. After the 8th and 12th days other common saprophytes and bacteria appeared, and in some cases no Phytophthora could be found. Except for the first day of burial, rotting was more severe close to the surface. Checks in moist chambers remained uninfected. When surface-disinfected, non-wounded, healthy pods were suspended in the air just above the surface of a cacao shell dump pile, 0.5 m high and 1.0 m high, infection was more severe close to the surface for the first 8 days. After the 12th day only slight differences in severity were observed at the different levels. Infection of the peduncles or upper part of the pods was seldom observed, in most cases the majority of the infected area occurring on the lower half. Rain must have washed wind-borne spores down to the lower halves of the pods when subsequently moist conditions for germination prevailed, while pods just above the surface of the dump pile could have been inoculated by rain splash containing spores. Control of pod rot by sanitation and fungicides is briefly discussed.

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NOTES ON THE CONTROL OF BLACK POD AND WITCHES' BROOM DISEASES IN TRINIDAD

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Together with other cacao countries, Trinidad early reported the presence of black pod disease (Phytophthora palmivora Butler) which attacked the pods, stem and young shoots of Theobroma cacao L. Some control has probably always been achieved by fairly frequent harvesting and spraying with Bordeaux mixture was attempted many years ago, but has never been regularly practised. The discovery of witches' broom (Marasmius perniciosus Stahel) in the Island in 1928 focussed attention on this disease and thereafter work was concentrated on it rather than on black pod.

These two diseases, in their pod symptoms, are often confused, and it is therefore difficult to estimate the losses due to one or the other alone. It is often best to consider them together. Black pod disease is most serious in the wetter areas (over 100 ins. of rain per annum) and it is strictly seasonal, becoming severe towards the end of the wet season - October to December (Baker 1953). In the wetter eastern districts recent records in a spraying experiment indicated that black pod disease could be responsible for heavier losses than witches' broom disease when these are expressed as the percentage of infected pods in the total number reaped. In a relatively drier, western area, at River Estate (the cacao experiment station of the Imperial College of Tropical Agriculture), witches' broom disease causes the greater losses. Determining losses due to black pod disease as a percentage of infected pods is not, however, the most accurate method of assessment as it leads to overestimation (Owen 1951). A pod promptly reaped in which the symptoms have only just begun to show will give good beans, and even if the symptoms are far advanced "black cacao", readily marketable, can still be prepared. On the other hand, practically all the beans in all pods attacked by witches' broom disease are destroyed and therefore numbers of diseased pods are a fair indication of losses. With witches' broom disease pods are safe from infection once they have reached a length of about 8 cms. and are 2 months old (Dale 1946). Black pod disease can attack and destroy pods of any age and losses from this disease

have always been thought to be mainly due to infection of full grown or almost full grown pods. Recently McLaughlin and Bowman (1952), in Costa Rica, showed that the fungus will attack a high proportion of the cherelles. In Trinidad, Leather (unpublished) found that infection of young cherelles was much less than that of larger pods. Even if many cherelles are attacked the losses will not be proportional to the number infected because a high percentage of cherelles would have wilted anyhow in spite of infection of the cherelles and the measurement of actual losses in wet cacao need further study. Death of the flowers due to P. palmivora is probably unimportant in its effect on yield, but canker may develop from infected cushions.

The only cultural practice which has been clearly shown to reduce losses through black pod disease is frequent harvesting (Owen loc. cit.). This aspect has been given prominence in Nigeria and the Gold Coast where reaping is only done once every 6-8 weeks, and where it has not, so far, been possible to achieve more frequent harvesting. Where spraying is not possible some control may be practicable by a method of inspection and removal of infected pods (Thorold 1953a). In Trinidad, harvesting is done approximately once every 4 weeks and many pods which would otherwise be lost are saved. More frequent pickings are generally not possible, firstly, because of labour problems, and secondly because the amount of cacao harvested would often be too small to allow of proper fermentation.

Spraying pods with Bordeaux mixture has been carried out in most cocoa countries at one time or another and it has recently been demonstrated, in Nigeria, that under certain conditions it is economic (Thorold loc. cit.). Spraying in Costa Rica, reviewed by Orellana (1953), is complicated by the prevalence of leaf as well as pod infection; a complication which does not occur in Trinidad or apparently in Nigeria. Recent trials carried out by us at the Imperial College of Tropical Agriculture have shown that copper fungicides are effective in controlling witches' broom disease and similar results were obtained by Thorold (1953b). In Trinidad the heaviest losses from this disease coincide with the time when black pod infection is also at its maximum. Further, these two disease maxima occur when most of the crop is ripening. Therefore it is possible that we may be able to control both diseases with one spraying schedule. The "dry" season in the first few months of the year delays the onset of serious attack until the latter part of the year and therefore spraying need only be carried out between July and December. In an experiment in a wet area (100-130 ins. per annum) five applications of fungicides were

made between July and November at intervals of 4 weeks. Black pod disease was more prevalent than witches' broom disease and both were controlled by copper sprays. On the unsprayed plots losses amounted to 50.5%; cuprous oxide reduced them to 20.2% and copper oxychloride to 21.1%. Lime sulphur, tetra methyl thiuram disulphide and zinc dimethyl dithiocarbamate gave little control of either disease. From earlier experiments we estimated that spraying would be only worth while on fields yielding at least 800 lbs. of dry cocoa per acre and where pod losses of at least 15-20% could be expected. Losses on this scale are more likely to occur in wetter areas and the development of a single spray programme to control black pod and witches' broom diseases in these areas seems to be well worthwhile.

A third method of control, the development of resistant varieties, is most important and has been the most neglected. I consider that a higher priority should be given to this aspect than to any other. A first requirement is a laboratory technique to test whether a variety is resistant or not. P. palmivora produces several spore forms and occurs in the field in different strains. These require more careful study than has hitherto been devoted to them. Laboratory tests must obviously be made, in the first instance, with the most abundant spore-form of the commonest strain. Any promising resistant material could later be tested against other forms and strains. Simply, the technique recently developed so far in Trinidad has been to grow a strain of the fungus isolated from a cacao pod on oatmeal agar and get from these cultures suspensions of zoospores - one of the spore forms. Zoospores cannot be obtained in sufficient numbers unless the temperature is 18-22°C (Gadd 1924) and in Trinidad this is only reached at night. But active zoospores can be obtained any time during the day if the cultures are incubated at this temperature for one hour. Sterile water or 0.5% sugar solution at the same temperature is then added to the cultures and left to stand a further hour. The water or sugar solution, now containing motile zoospores released by the fungus, is next filtered through sintered glass of a porosity which only allows the passage of these zoospores. The inoculum is then ready and must be used immediately. This simple artificial cooling treatment enables inoculations to be done at any time whilst under natural conditions they could only be made at night.

Pure zoospore suspensions prepared in this way have successfully infected pods, young and mature leaves and seedlings. Well grown pods detached from the tree and seedlings can be placed in damp chambers either in the greenhouse or the laboratory and inoc-

ulated by spraying or brushing on the inoculum. For critical tests a simple glass ring technique enables a known quantity of zoospores to be applied to a known surface area of a pod. Portions of leaves removed from the field can be placed in damp petri dishes and inoculated. Infection on susceptible material is so rapid that young leaf tissue is killed before wilting occurs. Infection of "hardened" leaves is readily obtained though its development is slower than that on younger ones.

Although no cacao has yet been satisfactorily demonstrated as highly resistant either to pod or leaf attack, observations by Orellana (loc. cit.) and Parham (1952) indicate that pod resistance possibly occurs. SIC 28, a Brazilian clone reported to show considerable resistance to black pod disease, has been recently established in Trinidad. Leaves of this clone can be readily infected by the fungus and show no difference to comparable material from ICS 1. Two Amazon clones SCA 6 and SCA 12 have been found to be very highly resistant to witches' broom disease in Trinidad. Field records suggest that these clones may also be somewhat resistant to other pod diseases. In several randomised experiments a total of 45 full-grown detached pods each of SCA 6 and ICS 1 were inoculated by brushing a zoospore suspension on them. Infection occurred in 26 of the ICS 1 pods and in 6 of those of SCA 6.

We hope to examine the wide variety of material now in Trinidad for evidence of resistance. A beginning was made in January this year. Work on this aspect of control must not neglect any possible relationship between pod infection, leaf wilt and stem canker. Attention has been confined so far to pod resistance. Is there any correlation between this and canker formation? Will a tree whose leaves show some resistance have pods which do so too?

SUMMARY

In the wetter areas of Trinidad (over 100 inches rain) black pod (Phytophthora palmivora) causes serious losses, whereas in the drier regions, witches' broom (Marasmius perniciosus) causes great losses. In pods attacked by witches' broom, all the seeds are damaged. Beans can still be prepared from pods heavily infected with black pod. The author discusses 3 methods of control: 1. Frequent harvesting, 2. sprays of copper fungicides and 3. resistant varieties. Included in the paper there is a detailed discussion on isolating a fungus strain from a pod and growing it on oatmeal agar. This is discussed in relation to making inoculations to study variety or clone resistance. (A.L.E.).

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MASS SELECTION OF CACAO SEEDLINGS FOR RESISTANCE TO WITCHES' BROOM

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INTRODUCTION

The single most important factor responsible for reduced production of cacao in Ecuador is the Witches' Broom disease caused by Marasmius perniciosus. The fact that the fungus attacks only rapidly growing tissues such as the unfolding vegetative shoot, growing pod, and flower cushion, implies that control by means of protective fungicides is exceedingly difficult since the maintenance of coverage on a rapidly growing surface necessitates frequent respraying at short intervals. This difficulty is further compounded by the fact that the season of greatest infection coincides with the rainy season so that spraying operations would have to be conducted during the time of year when passage through the field with heavy equipment is most difficult.

The method of control which would be the simplest and most economical for the farmer would be, of course, the use of varieties resistant to the disease. Clones resistant to Witches' Broom have been developed (1) from collections made in the Amazon by Pound but have the disadvantage of low yield and poor commercial quality. The genetic heterogeneity of cacao is such, however, as to offer the possibility of finding individuals which possess a worth-while level of resistance to the disease as well as good commercial quality.

CACAO POPULATION OF ECUADOR

The cacao population of Ecuador is composed of Cacao Nacional, a relatively uniform variety indigenous to the area, and an extremely variable introduced population of segregating Trinitario hybrids.

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Cacao Nacional is a very high quality cacao which is, unfortunately, extremely susceptible to Witches' Broom disease. Little Cacao Nacional has been planted by the cacao growers of Ecuador in recent years, the tendency being to plant Trinitario instead because it displays, on the average, somewhat greater resistance to Witches' Broom than the Cacao Nacional.

Trinitario cacao is usually referred to as "Venezolano" in Ecuador because the first introductions were thought to have come from Venezuela. The evidence obtained by Pound (1) in his exploration of the Amazon valley indicate that resistance to Witches' Broom is to be found in some segments of the Amazonian Forastero population. It is reasonable, therefore, to expect that varying levels of resistance might also be found in individuals of the segregating Trinitario hybrid population, since this represents the results of crossing between Forastero and Criollo. This supposition is supported by field observations that Trinitario trees do present an appearance of considerable variation in resistance to the disease and selections have been made on this basis. The presence of Criollo germ plasm in the Trinitario population introduces the possibility that a Trinitario seedling selected for resistance to Witches' Broom might yield a much better quality product than would a pure Forastero tree and might also have a desirable level of hybrid vigor. Crossing of the Trinitario introductions with the indigenous Cacao Nacional has further complicated the hybrid nature of the Trinitario complex and introduces the possibility of obtaining selections with quality derived from Cacao Nacional.

MASS SELECTION OF CACAO SEEDLINGS

a. Materials and Methods.- Seeds used in this program were obtained from various sources including the crop harvested from established clones and introductions growing at the Tropical Experiment Station.

The seedlings were grown in beds shaded by old cacao trees heavily infected with Witches' Broom disease so that they would have every opportunity to become naturally inoculated. In addition, they were artificially inoculated as often as possible under favorable weather conditions by spraying with spore suspensions of the fungus. With the exception of a single large planting of Cacao Nacional, the seedlings derived from each pod were separated in the seed beds with numbered stakes so that records could be kept of the behavior of the individuals derived from each pod. All plants which developed Witches' Broom were discarded. This process of roguing the diseased plants was carried out once each month.

The Marasmius sporophores from which the spores used in artificial inoculation were obtained were produced on Witches' Brooms held in structures resembling cold frames. It was found that a fairly steady production of sporophores could be maintained on these brooms distributed over bamboo slats in the bottoms of cold frames having covers of leaves. The brooms and the leaf covers were sprinkled with water one to three times daily depending upon the weather. Sporophores were harvested during most of the year except the driest and hottest part of the dry season. The spore suspension was prepared by shaking the sporophores in a flask of tap water.

Since the primary objective of the selection program was to eliminate as many susceptible plants as possible, no uninoculated controls were carried in the selection beds. Days favorable for inoculation were those featuring a precipitating mist in the morning. This precipitating mist is known in Ecuador as "garúa" and occurs quite commonly during the rainy season and during the first months of the dry season. On some days this mist may continue until noon. Inoculation was done between the hours of six and nine o'clock in the morning and inoculation was not attempted if the weather did not look favorable. The efficacy of this technique of inoculation was tested on seedlings growing in bamboo joints in the greenhouse with the results shown in Table 1.

TABLE 1

Effect of Inoculating Cacao Seedlings with *Marasmius perniciosus* Spores at Different Hours of the Morning

Time	Age of Plants	No. of Plants	No. developing brooms	No. remaining healthy
6:00 AM	20 days	19	13	6
8:00 AM	" "	19	13	6
10:00 AM	" "	20	15	5
CONTROL	" "	16	1	15
6:00 AM	8 months	20	6	14
8:00 AM	" "	20	7	13
10:00 AM	" "	19	6	13
CONTROL	" "	18	1	17

It appears from these data that time of inoculation is not important so long as atmospheric conditions are favorable as was mentioned above. It is apparent that the 20-day seedlings were

more susceptible to inoculation than the seedlings eight months old. It is believed that the reason for this is that seedlings of the same age will produce their first flush of growth at approximately the same time, whereas later flushes will not be as nearly simultaneous so that, at any one time, some of the growing points will be in a susceptible condition while others will not. An attempt was made, therefore, to inoculate the seedlings during their first flush of growth. It is believed that the artificial inoculation was well worth while as an auxiliary to the natural inoculum available and as a means of prolonging somewhat the length of season during which inoculation would occur. The infection of a single control plant in each age group is not thought to reflect upon the indicated effectiveness of the inoculation. These may be plants accidentally inoculated during the spraying of the treated plants or could represent natural infection, as there was abundant natural inoculum in the vicinity.

b. Evidence of variation in degree of resistance to Witches' Broom disease among populations of cacao.- An examination of the data thus far accumulated in the mass selection program demonstrates very strikingly the difference in degree of resistance to Witches' Broom disease among different cacao populations and especially between Cacao Nacional and the segregating Trinitario hybrids. Fig. 1 shows a comparison of Cacao Nacional and Trinitario in terms of the survival of seedlings after a two-year period of roguing for Witches' Broom infection. The Trinitario seedlings are divided between those derived from yellow pods and those from red pods. The figures are based on plants surviving the two-year period of roguing for Witches' Broom. Those plants which were lost from other causes were disregarded. A total of 1357 Cacao Nacional, 1451 red Trinitario, and 1327 yellow Trinitario seedlings are included in this calculation. Only nine Cacao Nacional seedlings survived to the end of the two-year period while 200 red and 156 yellow Trinitario seedlings survived. Comparing the end points of the curves by means of the Chi-square test for independence as shown in Tables 2, 3 and 4, shows that both of the curves for Trinitario seedlings are very significantly different from the curve for Cacao Nacional while there is no significant difference between the red and yellow Trinitario.

This result supports field observation that Cacao Nacional does not appear to possess resistance to the Witches' Broom disease and the nine surviving plants are very probably escapes. Since Cacao Nacional is a true breeding variety with little variability, it is an unlikely entity in which to search for resistance. The behavior of the Trinitario, on the other hand, is quite encouraging. Being a mass of segregating hybrids having great variability, the

contrast of its behavior with that of Cacao Nacional over the two-year period suggests very strongly that there is an excellent chance of finding individuals in the group which possess useful levels of resistance to the disease. It is interesting to note that the data show no difference in behavior between Trinitario seedlings derived from red or yellow pods. This suggests that pigmentation is not associated with resistance to Witches' Broom.

TABLE 2

Incidence of Witches' Broom Infection in Populations of Cacao Nacional and Red Trinitario Subjected to Two Years of Inoculation and Roguing

	Infected	Not Infected	Total
Cacao Nacional	1348	9	1357
Red Trinitario	1251	200	1451
	2599	209	2808

X^2 = 18.2 Significant at 99 - 1 odds.

TABLE 3

Incidence of Witches' Broom Infection in Populations of Cacao Nacional and Yellow Trinitario Subjected to Two Years of Inoculation and Roguing

	Infected	Not Infected	Total
Cacao Nacional	1348	9	1357
Yellow Trinitario	1171	156	1327
	2519	165	2684

X^2 = 14.3 Significant at 99 - 1 odds.

TABLE 4

Incidence of Witches' Broom Infection in Populations of Red and Yellow Trinitario Subjected to Two Years of Inoculation and Roguing

	Infected	Not Infected	Total
Red Trinitario	1251	200	1451
Yellow Trinitario	1171	156	1327
	2422	356	2778

X^2 = 2.56 Not significant at odds of 19 - 1

In Table 5 are shown data for seedlings from each pod having 25 or more seedlings on which records were kept in the Trinitario groups shown in Fig. 1, regardless of pigmentation. It can be seen that there is a wide variation in the behavior of the seedlings from the different pods with a few showing 50% or more survival while a great many others showed no survival at all. Testing these data for independence by means of the Chi-square test for independence discloses that the pods separate roughly into three groups, one containing 33 pods displaying from zero to about 15% survival, a second containing 10 pods displaying from 16 to about 40% survival, and a third containing 5 pods which show from about 40 to about 55% survival.

TABLE 5

Evidence of Witches' Broom Infection in Seedlings Derived from Individual Pods of Trinitario Population over Two-Year Period

Class	Pod No.	Infected	Not Infected	Total
A	38	13	15	28
	8	16	17	33
	3	14	14	28
	1	18	13	31
	36	22	15	37
B	26	24	15	39
	45	20	12	32
	24	18	9	27
	41	20	8	28
	7	18	7	25
	5	26	9	35
	21	19	6	25
	31	23	5	28
	25	24	5	29
	9	21	4	25
C	39	23	4	27
	34	22	3	25
	2	30	4	34
	40	23	3	26
	13	24	3	27
	20	38	4	42
	44	23	2	25
	32	24	2	26
	29	26	2	28
	46	27	2	29
	35	28	2	30

Class	Pod No.	Infected	Not Infected	Total
C	4	29	2	31
	11	32	2	34
	30	24	1	25
	28	24	1	25
	17	24	1	25
	48	25	1	26
	22	25	1	26
	15	27	1	28
	6	28	1	29
	33	34	1	35
	27	35	1	36
	19	36	1	37
	42	37	1	38
	47	36	0	36
	43	27	0	27
	37	30	0	30
	23	31	0	31
	18	25	0	25
	16	28	0	28
	14	35	0	35
	12	29	0	29
	10	33	0	33

This distribution indicates quite a wide variation among individuals of the Trinitario population in their resistance to Witches' Broom and suggest that the Trinitario population is just as variable in this characteristic as it is in yield, pod size, pigmentation and other attributes.

Selection for resistance to Witches' Broom in this manner is based upon the theory that the most susceptible individuals in the population will become infected and be eliminated very rapidly. Those which survive this initial elimination will include plants of varying degrees of resistance plus some chance escapes. Since the problem is not, necessarily, to find an absolutely immune plant, the desirability of subjecting the seedlings to two years of intensive inoculation and roguing is questionable. It is thought that trees may develop a few brooms and still possess sufficient resistance to the disease to make them far superior to the present cacao population. Hence, seedlings eliminated by the development of a single broom late in the inoculation period may, nevertheless, still have possessed a relatively high level of resistance to the disease. Highly significant differences in survival are shown by plants of the different pop-

ulations subjected to only one year of inoculation and roguing and, although it is clear that the survivors will include a larger number of susceptible escapes, this disadvantage may be offset by the retaining of potentially desirable plants which would otherwise be lost. Removal of plants from the seedling beds at an earlier age also reduces the losses from seedbed diseases such as anthracnose and from the mortality to be expected in transplanting.

Table 6 shows a comparison of the survival of Cacao Nacional and Red Trinitario subjected to inoculation and roguing only during the year 1951. It can be seen that the performance of these two groups is quite significantly different and it seems safe to assume that the great bulk of highly susceptible individuals was eliminated from the Red Trinitario population.

In Table 7 Cacao Nacional is compared with a small group of plants derived from pods harvested from selected trees. The group of selected pods includes 15 pods of which 10 were harvested from four trees that had given previous indication of being above average in resistance to the disease. It can be seen that the group including the progeny of the selected trees has performed in a manner definitely superior to that of the unselected Red Trinitario. In Table 8 this population is compared with the unselected Red Trinitario and it appears that the level of resistance in the group is undoubtedly much higher, indicating that, in this group, the resistance of the mother plants is being passed along in appreciable degree to a rather high percentage of the offspring. This means that, since the offspring will be segregating for other characters as well, plants having more desirable yield and quality as well as resistance may well appear among them.

TABLE 6

Incidence of Witches' Broom Infection in Population of Cacao Nacional and Red Trinitario Subjected to One Year of Inoculation and Roguing

	Infected	Not Infected	Total
Cacao Nacional	1425	161	1586
Red Trinitario	464	96	560
	1889	257	2146

X^2 = 19.2 Significant at 99-1 odds.

TABLE 7

Incidence of Witches' Broom Infection in Population of Cacao Nacional and Selected Trinitario Subjected to One Year of Inoculation and Roguing

	Infected	Not Infected	Total
Cacao Nacional	1425	161	1586
Selected Trinitario	170	137	307
	1595	298	1893

X^2 = 230.0 Signigicant at 99-1 odds.

TABLE 8

Incidence of Witches' Broom Infection in Populations of Unselected and Selected Trinitario Subjected to One Year of Inoculation and Roguing

	Infected	Not Infected	Total
Red Trinitario	464	96	560
Selected Trinitario	170	137	307
	634	233	867

X^2 = 178.9 Significant at 99-1 odds.

FIELD PLANTING FOR FURTHER SELECTION

During the 1952 rainy season, 752 of the survivors of the mass selection program were transplanted to permanent field locations at a spacing of four by five meters. Losses incurred in transplanting were replaced in 1953 with plants still remaining in the seed beds. Deaths from various causes has reduced the number of surviving plants to 698.

No plants which had developed brooms were transplanted to the field and the plants were not rogued for Witches' Broom after having been established in the field planting. Records were taken each month of the numbers of Witches' Brooms developing on each plant. Conditions are not as favorable for inoculation with Witches' Broom in the field planting as they were in the seed beds and no artificial inoculation has been practiced. The scattered distribution of suceptible plants throughout the planting, however, indicates that the distribution of inoculum is fairly uniform.

The records show that during the two-year period since the establishment of the field planting, 251 plants have developed no Witches' Broom, 382 plants have developed from one to nine brooms each, and 65 plants have developed ten or more brooms. The best plants in this group will be selected for clonal multiplication.

SUMMARY

The genetic heterogeneity of cacao is such as to offer the possibility of selecting individuals which are resistant to Witches' Broom disease. Investigation has shown that Cacao Nacional, the native cacao population of Ecuador, possesses little resistance to Witches' Broom, while wide variations in resistance have been found among individuals of the introduced Trinitario cacao. Statistically significant differences in susceptibility to Witches' Broom have been noted between seedlings of Cacao Nacional and seedlings of the Trinitario population. Statistically significant differences have also been noted within the Trinitario population itself.

Mass selections of cacao seedlings for resistance to Witches' Broom disease by means of artificial inoculation of seedlings and subsequent roguing of the plants which develop symptoms of the disease, has been in progress at the Tropical Experiment Station of Ecuador since 1949. This has resulted in the establishment of a field planting of 698 survivors of the selection program. Monthly records are being kept on these trees with the objective of selecting the best plants among them for clonal multiplication.

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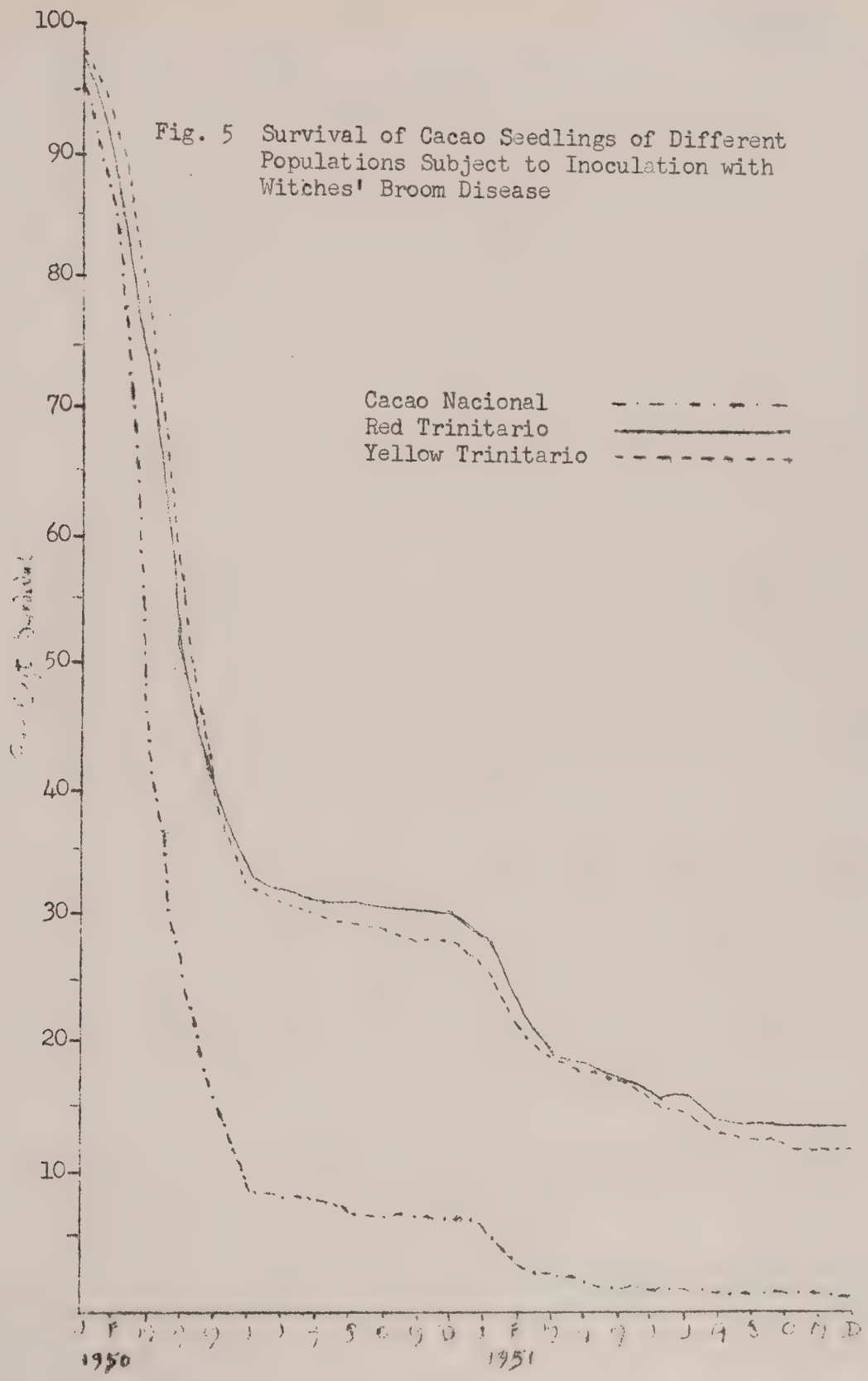

Fig. 5 Survival of Cacao Seedlings of Different Populations Subject to Inoculation with Witches' Broom Disease

EVALUATION OF CLONES OF CACAO FOR RESISTANCE TO WITCHES' BROOM

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INTRODUCTION

Numerous collections of outstanding cacao trees from all parts of the Ecuadorian coastal plain were made during the years 1945 and 1946 by Dr. Robert L. Fowler, at that time horticulturist at the Tropical Experiment Station. These collections were made by taking bud wood from the selected trees and grafting the buds to suckers of cacao trees at the Experiment Station in order to establish promising clones. During the same period clones being studied in Trinidad and Costa Rica were imported and established at the Station. In addition seed of special types of cacao were introduced from time to time from Colombia, Venezuela, Brazil and Peru. The clones and seedling introductions in the Station collection now number 310 and represent an assemblage of great potential value from the point of view of important qualities such as high yield and resistance to disease.

Since resistance to Witches' Broom is an extremely important characteristic for the success of cacao clones under Ecuadorian conditions, the desirability of establishing some system for the quantitative evaluation of this trait is evident. By evaluating the clones from data accumulated from the original plants established at the Station, considerable time could be saved as it is only recently that rooted cuttings of the clones have begun to be planted in randomized field experiments for direct comparison. Several years will be necessary to accumulate sufficient data to compare their resistance.

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EVALUATION OF CLONES

Pound (2), dealing with the seedling offspring of plants selected in the Amazon for resistance to Witches' Broom, devised a criterion of resistance based upon the number of brooms produced on a plant during a given year. According to this system, a plant is thought to be too susceptible for further consideration if it develops more brooms during a given year than it has years of age. A plant one year old would be retained if it developed no more than a single broom during its first year of growth; a plant two years old would be allowed two brooms during its second year or a total of three in its first 2 years of life; a plant three years old would be retained if it did not have more than three brooms during its third year or more than six during its life up to that time. If, however, a three-year old plant developed more than three brooms during its third year or more than six during its three years of life, it would be discarded. This screening technique has the virtue of simplicity and of providing a numerical criterion, however arbitrary, upon which to base selection. The selection would, one might expect, become more stringent as the plants become older since the number of shoots upon which brooms could develop would increase more rapidly than the numerical age of the plants.

Although it is felt that small differences in resistance among clones can be determined satisfactorily only by replicated field experiments, yet certainly the more susceptible members of a group of clones can be readily eliminated by a screening process such as described above. The authors have been using a modification of the Pound technique in screening clones for resistance to Witches' Broom. A figure termed the "broom-age ratio" is calculated for each clones by dividing the mean number of brooms produced by all members of the clone of the same age by the age in years. While Pound was dealing with the single individuals of a seedling population, the broom-age ratio is determined from the behavior of all of the available plants of a clone through the use of a mean figure for the brooms produced. It is thus a more elastic screen and allows for a certain amount of latitude with regard to site and the physiological condition of members of the clone. Clones having broom-age ratios of 1.0 or less have been considered as probably resistant, those having ratios of between 1.0 and 1.5 as intermediate, and those with ratios of over 1.5 as susceptible. Obviously, this system is more efficient at detecting the susceptible clones than the resistant ones because of the possibility that susceptible clones might escape infection in any one season and thus temporarily give the impression of being resistant.

A list of 77 of the Station clones is shown in Table 1. These clones were all between 58 and 63 months of age at the end of 1951 and are considered as having been five years old at that time for the purpose of this analysis. Only clones having at least three plants of this age are included. The clones are grouped in ascending order of the mean numbers of brooms per clone. The analysis of variance, carried out as described by Snedecor (3) for classes having unequal frequencies, is shown in Table 2 and indicate highly significant differences among the means of the clones. Comparing pairs of means by the "t" test as described by Goulden (1), shows that they can be separated into groups approximately as indicated by the breaks in the column of Table 1.

TABLE 1

Witches' Broom production by five-year old plants of seventy-seven clones of cacao during 1951.

Clone	No. of Plants	No. of Brooms produced	Mean Brooms per plant	Broom-age ratio	Group
21	6	18	3.0	0.60	A
157	3	9	3.0	0.60	
140	5	17	3.4	0.67	
275	10	36	3.6	0.72	
277	7	30	4.3	0.86	
169	11	50	4.5	0.90	
27	3	15	5.0	1.00	
143	3	16	5.3	1.06	
141	9	53	5.9	1.18	
166	3	20	6.7	1.34	
155	3	21	7.0	1.40	
206	6	46	7.7	1.54	
177	6	48	8.0	1.60	
144	7	58	8.3	1.66	
34	4	34	8.5	1.70	
30	4	37	9.3	1.86	
185	3	29	9.7	1.94	
23	6	60	10.0	2.00	
181	9	92	10.2	2.04	
43	4	43	10.8	2.08	
55	5	57	11.4	2.28	
62	8	92	11.5	2.30	
121	5	59	11.8	2.36	
208	3	36	12.0	2.40	
147	8	102	12.8	2.56	
93	3	40	13.3	2.66	
180	6	81	13.5	2.70	

Clone	No. of Plants	No. of Brooms produced	Mean Brooms per plant	Broom-age ratio	Group
78	9	124	13.8	2.76	A
167	4	59	14.8	2.96	
205	5	76	15.2	3.02	B
46	4	62	15.5	3.10	
90	3	47	15.7	3.14	
171	6	94	15.7	3.14	
97	4	64	16.0	3.20	
66	6	102	17.0	3.40	
94	5	85	17.0	3.40	
96	9	154	17.1	3.42	
28	7	121	17.3	3.46	
81	3	52	17.3	3.46	
25	5	90	18.0	3.60	
159	4	73	18.3	3.66	
19	13	248	19.1	3.82	
63	9	176	19.6	3.92	
179	19	377	19.9	3.98	
164	3	60	20.0	4.00	
50	3	61	20.3	4.06	
51	5	105	21.0	4.20	
65	5	105	21.0	4.20	
156	8	169	21.1	4.22	
70	3	66	22.0	4.40	
36	6	134	22.2	4.44	
92	3	68	22.7	4.54	
118	3	68	22.7	4.54	
160	9	205	22.8	4.56	
184	6	154	25.7	5.14	
44	7	190	26.1	5.22	
69	6	158	26.3	5.26	
161	5	127	26.5	5.36	
38	6	159	26.8	5.36	
39	4	106	26.8	5.36	
49	5	138	27.3	5.46	
67	6	167	27.8	5.56	
95	4	111	27.8	5.56	
80	4	118	29.5	5.90	
20	4	125	31.3	6.26	
162	16	508	31.8	6.36	C
183	4	127	31.8	6.36	
16	18	606	33.6	6.72	
58	3	108	35.0	7.00	

Clone	No. of Plants	No. of Brooms produced	Mean Brooms per plant	Broom-age ratio	Group
40	5	176	35.2	7.04	C
61	3	116	38.8	7.76	
42	6	245	40.8	8.16	
60	4	176	44.0	8.80	
56	3	134	44.6	8.92	
182	4	188	47.0	9.40	
48	8	425	53.2	10.64	
267	5	402	80.0	16.00	

TABLE 2

Analysis of Variance

Source of Variance	DF	SS	Mean Square
Total	448	171306.26	382.38
Between clones	76	73551.27	967.78
Within clones	372	97754.99	262.78

$$F = \frac{967.78}{262.78} = 3.68^{XX} \text{ (Significant at 99-1 odds)}$$

The clones are seen to separate into three broad categories having different mean levels of broom production. It is felt, because of the highly significant F value obtained in the analysis of variance, that these differences may be safely interpreted as resulting from qualities inherent in the clones themselves and not as the result of pure chance. Undoubtedly, however, irregularities in the distribution of inoculum, moisture, shade, and other factors plus the fact that some of the clones are represented by comparatively few plants, have resulted in errors in the location of some clones in the list. Very likely some clones present in Group A really belong in Group B. As was pointed out earlier, the susceptible clones are separated with much greater certainty than the resistant onces.

It can be seen that Group A includes clones having broom-age ratios as high as 2.96. This is much higher than the level of 1.5 which had been set as the limit previously. It is quite likely, however, that the statistical analysis would have provided a narrower grouping had it been possible to include larger numbers of plants in each clone. Attention is still focused on those clones having broom-age ratios not greater than 1.5 as showing the most promise of being resistant to the disease.

In Tables 3 and 5 are listed smaller groups of three and four year old clones, respectively. The analysis of variance of these are given in Tables 4 and 6. It can be seen that the grouping of the clones follows a similar pattern with these younger plants except that the analysis of variance of the three year old clones gives an F value significant only at odds of 19-1 rather than 99-1.

TABLE 3

Witches' Broom production by four year old plants of sixteen clones of cacao during 1951

Clone	No. of plants	No. of Brooms produced	Mean Brooms per plant	Broom-age ratio	Group
227	3	2	0.67	0.17	A
139	4	4	1.00	0.25	
220	4	4	1.00	0.25	
225	4	4	1.00	0.25	
272	4	5	1.25	0.31	
117	3	13	4.33	1.08	
273	7	44	6.29	1.57	
114	5	33	6.60	1.65	
65	5	42	8.40	2.10	
24	14	134	9.57	2.39	B
37	14	137	9.79	2.45	
278	3	39	13.00	3.25	
62	4	64	16.00	4.00	
212	3	79	26.33	6.58	
238	3	91	30.33	7.58	C
211	3	130	43.33	10.83	

TABLE 4

Analysis of Variance

Source of Variance	DF	SS	Mean Square
Total	83	13564.32	163.43
Between clones	15	7448.60	496.57
Within clones	68	6115.72	89.94

$$F = \frac{496.57}{89.94} = 5.52^{XX} \text{ (Significant at 99-1 odds)}$$

TABLE 5

Witches' Broom production by three year old plants of fourteen clones of cacao during 1951

Clone	No. of plants	No. of Brooms produced	Mean Brooms per plant	Broom-age ratio	Group
31	4	6	1.50	0.50	A
181	4	9	2.25	0.75	
177	4	14	3.50	1.17	
275	9	32	3.56	1.19	
208	3	14	4.67	1.56	
156	6	32	5.33	1.78	
164	9	50	5.56	1.85	
161	9	57	6.33	2.11	
165	6	40	6.67	2.22	
157	5	44	8.80	2.93	
159	9	81	9.00	3.00	
179	5	50	10.00	3.33	B
162	9	134	14.89	4.96	
160	6	131	21.83	7.28	

TABLE 6

Analysis of Variance

Sources of Variance	DF	SS	Mean Square
Total	87	8346.86	95.94
Between clones	13	2273.02	174.85
Within clones	74	6073.84	82.08

$$F = \frac{174.85}{82.08} = 2.13^{\text{¥}} \quad \text{(Significant at 19-1 odds)}$$

TABLE 7

Clones having broom-age ratios below 1.0 in 1951 and 1953

Clone No.	Broom-Age Ratio 1951	Broom-Age Ratio 1953
157	0.60	0.43
140	0.67	0.00
275	0.72	0.17
277	0.86	0.00
169	0.90	0.14

The total Witches' Broom production during 1953 was lower than that during 1951, resulting in a general lowering of the broom-age ratio. Of the clones discussed in this paper, however, only five were found to maintain broom-age ratio below 1.0 for both years, as shown in Table 7.

VARIABILITY IN THE BROOM-AGE RATIO

The broom-age ratio has been found to fluctuate widely from year to year. One factor responsible for this fluctuation is the quantity of rainfall occurring during the year. The rainfall in 1951 was 107 inches; in 1952, 58 inches, and in 1953, 120 inches. The numbers of dead Witches' Brooms harvested from the plants under observation during those years were slightly in excess of the following figures: 29,000; 9,000 and 22,000, respectively. This shows that there was a serious curtailment in Witches' Broom production during the year 1952 associated with the relatively low rainfall of that year. The production of brooms was so low, in fact, that the figures obtained were useless for the purpose of estimating the susceptibility of the plants. The figures also show that more brooms were produced in 1951 than in 1953, although the rainfall was greater in the latter year than in the former and the plants were also two years older. It would seem that factors other than the total annual rainfall are affecting the incidence of Witches' Broom disease on these plants. The actual distribution of rainfall throughout the season, doubtless has an effect, as well as such factors as the timeliness of cleaning, and the removal of old shade trees and old cacao trees which had acted as sources of inoculum.

SUMMARY AND CONCLUSIONS

Analysis of variance of the mean numbers of Witches' Brooms produced by clones of cacao under study at the Tropical Experiment Station shows highly significant differences among the clones in resistance to Witches' Broom Disease.

The use of broom-age ratios is suggested for the purpose of evaluating clones of cacao for resistance to Witches' Broom Disease when the plants are not arranged in formal experimental designs. Five clones of a group of 77 on which useful data are available since 1951 were found to maintain ratios below the level of 1.0 for the years 1951 and 1953 when Witches" Broom Disease was severe.

Since the measurement of resistance to Witches' Broom Disease in terms of numbers of brooms produced is predicated upon the assumption that the numbers of brooms produced by resistant plants

will be more narrowly distributed about a much smaller mean than will those produced by susceptible plants, it is to be expected that the resistant plants should display much less fluction in the broom-age ratio. A sudden wide fluctuation in the broom-age ratio of a clone thought to have been resistant would be sufficient cause to consider that clone as one which was susceptible but had escaped heavy infection up to that time. The more susceptible clones produce much higher numbers of brooms which can be much more widely distributed about higher means and thus provide the opportunity for much greater fluctuation in the broom-age ratio. Before being considered resistant, a clone should have maintained a consistently low broom-age ratio during several years and under severe disease conditions.

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"BUBA" OR CUSHION GALL OF CACAO IN NICARAGUA

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There is an abnormal condition characterized by a hypertrophy of the flower cushions that was found developing along the fan-branches and on the trunks of old cacao trees in Nicaragua. It also occurs on branches of chupons and occasionally on trees between three and four years of age. The affected trees, particularly the older ones become unproductive. From occasional abnormally enlarged cushions a few normal flowers may develop which eventually grow to full size pods but such occurrence is uncommon. The affected parts of cushions resemble dark-brown, cauliflower-like, hemispherical galls varying in size from 1/3 to 3 inches in diameter. In some cases more than one gall arises from a single flower cushion.

Rorer (1) in 1911 mentioned a somewhat similar condition as that described, on a few scattered trees in Trinidad called "male" cacao. Nowell (2) in 1923 described the presence of excrescences on trunks of cacao trees in the cacao-growing areas of the Lesser Antilles.

Cushion gall was observed also by Kevorkian (3) in 1945 in the Rivas area of western Nicaragua, where at present it seems to be more severe than in other areas. Recently, surveys (4, 5) revealed that its occurrence reaches along the rio Escondido as far north as Granada in Nicaragua. Kevorkian also reported the presence of cushion gall in the Bocas del Toro area of Panama, although there he found it was not as abundant as in Rivas. He observed small knobs or galls on the floral cushions of cacao trees growing at the Canal Zone Experimental Garden and also in an abandoned cacao plantation in Panama along the highway between Summit and Gamboa, near the latter. Similar gall-like structures have also been observed by Kevorkian in mango trees used as wind-breaks in the Buenos Aires area, and at the Haciendas San Lucía and El Palmar in Nicaragua. Orellana (4) observed galls on the wild avocado "tepe aguacate" (Persea sp.) near Rivas.

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A gall-like formation occurring on flower cushions in cacao trees in Costa Rica does not seem to be identical with the type occurring in Nicaragua. This in Costa Rica is apparently related to self-incompatibility. There is a possibility that the Costa Rican type of abnormal growth is of the kind reported from Trinidad on "male" cacao. Small knobs or galls also occur in Costa Rica and in Nicaragua on the flower cushions on cacao trees. They also may be found sometimes at the insertion of large chupon branches. In several such examples, enlarged and elongated knobs appeared to have developed from adventitious roots of these chupons. When these knobs were sectioned it was found that they consisted of hardwood and were not the same as the "buba" or cushion gall. In many cases insect galleries occupied by larvae were found inside of these knobs.

The amount of infected trees in the Rivas area was estimated in 1945 by Kevorkian to be of the order of 25 per cent. In certain farms he reported that up to 50 and 75 per cent of the trees were seen with galls. This degree of incidence has since been corroborated.

There is no certainty about the cause of this disease. However, Kevorkian indicated it might be possible that it was a virus because of the systemic nature of the trouble. He observed mealy bugs in abundance on the trees and stated that these or other insects might serve as vectors. Other possible factors that have been suggested are infection by fungi, mineral deficiency or toxic effect, and even the result of inheritance. Cushion galls are certainly due to an excessive stimulation of adventitious buds.

Fresh galls of all sizes were collected by Orellana in the Rivas area and were preseved for study in solution of fixative FAA. Within a few days he sectioned these materials free-hand and examined them under the microscope. It was found that the internal structure of the gall appears somewhat porous and that it was formed by a whorl of buds as pointed out by Wellman (5), but that they branch and develop a massive growth of hypertrophied flower pedicels and other abnormal tissue. The cells of the cushions are enlarged and thick walled, and contain intracellular strands of what appear to be fungus mycelium. Isolations made by Orellana at Rivas in artificial media from fresh untreated pieces of tissue rendered colonies of Fusarium, Trichoderma, bacteria and a white, cottony, non-sporulating fungus, still unidentified. It seems quite significant also that the mites were found in profuse amounts both in the very youngest small-greenish-cushions galls as well as those of great age. Other larger insects were found also harbouring in the cushions, specially in old ones. Detailed

histological studies are in progress but these are not complete so that they may be reported.

In the Rivas area where this condition is very severe, Orellana (4) observed a conspicuous disorder on the leaves of cacao trees. These leaves were narrowed and mottled presenting a sickle-leaf appearance, as in the case of zinc-deficiency-symptoms. The mottling was very severe and resulted in an appearance very similar to what might be expected from a virus effect. There was also considerable dieback on the trees thus affected. In addition the Rivas area is constantly showered by volcanic ash originating in the Concepción volcano some miles away. The foliage of cacao trees can be seen whitened by the ashes. The effect of this has not yet been investigated.

Detailed research is necessary before any conclusions as to the cause of "Buba" or Cushion gall can be made. The observations thus far suggest many lines of investigation to be followed, as for example, a study of the isolated fungi and bacteria, presence of mealy bugs and mites, occurrence of mineral deficiency or toxicity, possible virus infection, effect of volcanic ash, and role of inheritance. Once the cause or causes have been determined a better idea of the potential destructiveness of this condition can be formed. Also, measures for its control may then be studied and recommended.

SUMMARY

"Buba" or Cushion gall is characterized by a hypertrophy of the flower cushions developing along branches and on trunks of old cacao trees. Young trees, 3-4 years old may also present this abnormality. The affected cushions resemble dark brown, cauliflower-like hemispherical bodies 1/3 to 3 inches in diameter. The affected trees appear to become increasingly unproductive with age. A somewhat similar condition was described by Rorer in Trinidad in 1911; by Nowell in the Lesser Antilles in 1923; and by Kevorkian in 1945 in Rivas, Nicaragua, who later reported cushion galls on cacao in Panama. A gall formation on cacao occurring in Costa Rica does not appear to be identical with Cushion gall of Nicaragua. There is the possibility that the Costa Rica type might resemble the Trinidad type. Small knobs or galls that occur on cacao are thought to be different from the Nicaraguan Cushion gall. There is no certainty about the cause or causes of this condition. Virus, fungi, mineral deficiency or toxicity effects, and inheritance have been indicated as possible causes. Isolations made in 1954 from the Nicaraguan Cushion galls rendered several species of fungi and bacteria. Mites and other insects were also found harbouring within Cushion galls.

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LA MALADIE "DU DESSECHEMENT DES EXTREMITES" DU CACAOYER AU CAMEROUN

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INTRODUCTION

La maladie existe au Cameroun depuis de nombreuses années; nous l'avons signalé, pour la premiere fois, à notre arrivée en 1950, dans la région de Bafia, à NTUI.

Il semble que depuis cette date, les tâches de cacaoyers atteints de déssèchement se soient multipliées, principalement dans la région du Dja et Lobo et dans la région du Ntem.

La plupart du temps, les planteurs interrogés répondent que la maladie n'est apparue que depuis peu de temps, deux ou trois ans au maximum. Il semble donc que nous assistons a l'heure actuelle à une extension inquiétante peut-être cyclique, de la maladie du "dessèchement des extrémités" du cacaoyer.

En 1952, l'aspect desseché de certaines plantations de la région du Dja et Lobo (sur la route de Sangmélima-Djoum et dans le canton de Bengbis) ayant inquiété les Services publics, nous fumes amenés à effectuer une mission dans cette région pour déter miner la cause de la maladie et en indiquer les remedes.

ETUDE DE LA MALADIE

I - Description Macroscopique

Attaques récentes

Sur les jeunes pousses et les gourmands. Présence de tâ ches lenticulaires allongées brun-foncé; l'extrémité de la jeune pousse ou du gourmand est souvent flétrie et de couleur noire, les memes tàches se retrouvent sur les pétioles.

Sur les rameaux aoûtés. Présence de dépressions et de fentes de l'écorce, cette derniere disparait souvent, laissant à nu les faisceaux fibreux.

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Attaques anciennes

Les jeunes pousses et les gourmands, desséchés à leur extrémité, sont morts.

Les feuilles dont les pétioles ont été atteints se dessèchent et tombent.

Les nouvelles pousses de remplacement sont à leur tour attaquées et meurent.

L'arbre a un aspect buissonneux.

L'arbre ne porte pas, ou presque pas, de cabosses.

II - Hypotheses

A priori, les hypotheses pour expliquer ce "Die back" étaient les suivantes:

Un sol ne convenant pas à la culture du cacaoyer. (Maladie physiologique-Maladie de carence).

Des conditions climatiques défavorables a la croissance normale du cacaoyer.

Une attaque d'un ou plusieurs cryptogames.

Une attaque d'insectes.

Après une étude approfondie, les conclusions furent les suivantes:

Terrain

Il est évident que dans un sol ne luis convenant pas (insuffisance de la couche humifère-nappe phréatique trop pres du systeme radiculaire-seuil latéritique pres de la surface) le cacaoyer végete mal, est rabougri, son système radiculaire est peu développé (pivot court, tordu, bifide, trifide, racines tracantes rares).

Mais le terrain ne peut à lui seul expliquer la maladie. Nous avons observé des cacaoyers en excellent état sanitaire et d'autres atteints d'un dessèchement accusé, sur des terrains présentant en coupe la même horizon.

Une étude pédologique a confirmé ces observations.

Climatologie

Pluies: La répartition quantitative et qualitative des pluies est sensiblement la même que dans les régions non atteintes.

Ensoleillement. Il est très tentant d'attribuer la maladie à l'ensoleillement, en effet, un très grand nombre de plantations présentant du dessèchement ont un ombrage insuffisant et meme quelque fois nul, mais certaines plantations bien ombragées présentent des cas typiques de dessèchement.

D'autre part, ni le terrain ni la climatologie ne peuvent expliquer la présence de lésions chancreuses sur les rameaux.

Présence de cryptogames. L'examen des lésions chancreuses lenticulaires sur les jeunes pousses permet de mettre en évidence la présence fréquente de:

Colletotricum gloeosporioides
Colletotricum sp.
Gloeosporium sp.
Fusarium sp.

Cependant toutes les lésions ne sont pas infestées, et nous avons pu conserver, en chambre humide, plusieurs morceaux de gourmands de 20 cm. de longueur, présentant des lésions caractéristiques, sans que ces lésions n'évoluent ni ne donnent naissance a des fructifications de cryptogames.

Ces lésions ne sont donc pas d'origine cryptogamique.

L'examen des chancres febreux, présents sur les bois aoûtés, nous a permis de mettre en évidence les formes microconidiennes et macroconidiennes de Fusarium decemcellulare, stade imparfait de Calonectria rigidiuscula (B. et Br.) Sacc.

Par ailleurs, nous avons observé sur des bois morts présentant des lésions chancreuses de nombreux périthèces de Calonectria rigidiuscula.

Il est à signaler d'autre part la présence de:

Divers Nectria
La forme conidienne (Stilbum) de Sphaerostilbe repens.
Botryodiplodia Theobromae.

Présence de capsides. Le fait essentiel est que danstoutes les plantations atteintes, nous avons trouvé des capsides.

L'espèce, de loin la plus fréquente, est: Sahlbergella singularis Hablund.

III - Conclusion

La maladie du dessèchement des extremités du cacaoyer au Cameroun a les mêmes causes que celle décrite en Gold Coast, c'est à dire: attaque de capsides (Sahlbergella singularis, Distantiella Theobromae) aggravée géneralement par l'attaque d'un cryptogame (Calonectria rigidiuscula) pénétrant a la faveur des piqures de ces punaises. Il est possible que des Nectria interviennent aussi; nous avons observé des fructifications de trois Nectria et de leurs formes conidiennes sur des boutures prélévées sur des arbres précédemment attaqués par des capsides: Nectria Ipomeeae, Nectria cremea, Nectria Nkoembonensis.

Les dégàts sont beaucoup plus importants lorsque le cacaoyer se trouve dans des conditions climatiques ou de sol ne lui convenant pas.

Methodes de lutte

Une série de traitements expérimentaux a montré qu'une taille sévère de tous les bois chnacrés, suivie d'une pulvérisation d'une bouillie mixte (Bouillie bordelaise inverse a 1,2% - H.C.H.1%) donne d'excellents résultats. Certains arbres improductifs l'année précédente portaient cette année plus de 80 cabosses.

Conclusion generale

Un traitement insecticide suffit théoriquement pour éliminer les dégàts de capsides d'une "tache", mais il est préférable de pratiquer un traitement mixte, car les arbressont affaiblis et résistent mal a toute attaque cryptogamique et que, les dégàts les plus graves sont observés lorsque les piqures des capsides sont contaminées par un champignon.

Mas avant de traiter, il est nécessaire de pratiquer une taille énergique afin de supprimer tous les bois présentant des lésions chancreuses, qui, si elles sont contaminées par Calonectria rigidiuscula, permettent a ce champignon de progresser et d'être la cause de la mort de grosses branches charpentières et même de l'arbre tout entier lorsque calui-ci est jeune.

Il est démontré que les capsides sont très sensibles à la plupart des insecticides. Le problème le plus important est de trouver des appareils permettant d'effectuer les traitements dans les conditions très spéciales des plantations de cacaoyers du Cameroun.

D'autre part comme les plantations peu ou pas ombragées sont plus touchées par le maladie, surtout les jeunes plantations, il sera nécessaire d'introduire un ombrage supplémentaire. Nous orientons a l'heure actuelle vers le planconnage qui permet de mettre en place immédiatement un ombrage a la hauteur voulue.

Les espèces qui semblent les plus intéressantes sont:

Alstonia congensis (Apocynée)
Lannea Welwitschii (Anacardiacée)
Antrocaryon Klaineum (Anacardiacée)

RESUME

La "Maladie du dessèchement des extremites" du cacaoyer au Cameroun est à l'heure actuelle une maladie en progression.

Des expériences de traitement ont montré que l'on pouvait obtenir la régénération de ces plantations atteintes par une taille sévère des arbres suivis d'une pulvérisation mixte (Bouillie bordelaise et H.C.H.).

Une équipe mobile de traitement, composée de deux camions équipés d'une "Buffalo-turbine", de pulvérisateurs et de poudreuses est en train de traiter la majeure partie des plantations atteintes le long des pistes; le nombre de passages et les dates optimales des traitements sont en cours de détermination.

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EFECTO DE TRES FUNGICIDAS EN EL COMBATE DEL PHYTOPHTHORA PALMIVORA EN ARBOLES DE CACAO

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Una de las causas de la baja producción en las plantaciones de cacao en Costa Rica, es sin lugar a duda, debida al ataque del Phytophthora palmivora Butl. Este hongo ataca a casi todas las partes del árbol (2), pero donde reside la mayor importancia económica es en las mazorcas.

Se han hecho muchas recomendaciones para el control del Phytophthora en cacao. El uso de variedades resistentes (las que actualmente no se conocen), las ha recomendado Dade (7), Ferrer (8), y Rorer (17). La poda, el buen drenaje, y el saneamiento del suelo han sido recomendados por Dade (7), Altson (1), Llano (11), Pérez (16), Garcés (9), Rorer (17), y Cifferri (5). Bryce (3) y Cook (6), han recomendado la recolección y la quema de las mazorcas enfermas. Aunque estos métodos han sido considerados como buenos, no son suficientes para el control del Phytophthora en regiones donde la precipitación es abundante y se distribuye con cierta regularidad a través de todo el año.

Orellana (14), dice que: "Una reducción de las pérdidas debidas a Phytophthora pudo obtenerse por medio de aspersiones con fungicidas probados y aplicados en tiempos oportunos hasta que se encuentren genes para resistencia y sean entonces fijados por cruzamiento".

Las aspersiones con Caldo Bordelés para controlar el Phytophthora en cacao han sido recomendados por Silva y Llellis (4) en Brasil, Ferrer (8), Llano (11), Londano (10), y Garcés (9), en Colombia, Silayan (18), en las Filipinas, Cook (6), en Puerto Rico, Nowell (13), en las Antillas Occidentales, y Rorer (17), en el Ecuador. Sin embargo, recientemente Naundorf (12), recomienda no aplicar fungicidas a base de cobre en las plantaciones de cacao. En caso de aplicar dichos fungicidas --según Naundorf-- éstos deben mezclarse con el ácido para-clorofenoxiacético y glicerofosfa-

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to cálcico, substancias, que anulan en gran parte la acción perjudicial de los fungicidas a base de cobre. En Fernando Po. (19), hace más o menos 20 años han estado usando el Caldo Bordelés en las plantaciones de cacao.

En el presente informe se presentan los resultados de un experimento en el que se compararon el Caldo Bordelés, el SR-406 (últimamente llamado SR-50), y el Dithane Z-78, para el control del Phytophthora en cacao. Este experimento fué diseñado y planeado en setiembre de 1950 por: J.Harvey McLaughlin y George F. Bowman; quienes estuvieron llevando la mayor parte de los registros de dicho experimento hasta fines de 1952.

MATERIALES Y METODOS

El experimento se llevó a cabo en la finca La Lola, Costa Rica. Los tratamientos fueron los siguientes: a) Caldo Bordelés, 4-4-50, aplicado cada 30 días; b) SR-406, 4 libras en 100 galones de agua, aplicado cada 30 días; c) Dithane Z-78, 4 libras en 100 galones de agua, aplicado cada 30 días; d) Caldo Bordelés, 4-4-50, aplicado cada 60 días; e) Testigo, sin tratamiento.

Se hizo una distribución de los tratamientos en bloques completos al azar, con 4 repeticiones para cada tratamiento. Los ingredientes activos del Dithane Z-78 y del SR-406 son el dicarbamato de zinc etileno y de n-triclorometil tiotetrahidroftalamida respectivamente; el primero es producido por la Casa Rohm & Haas, y el segundo por la U. S. Rubber. Se empleó más o menos un galón de fungicida por árbol en cada aplicación. El fungicida se aplicó al follaje por medio de mangueras de 55 metros de longitud, utilizándo una bomba "Bean Royal" de 600 a 800 libras de presión movida por un motor "Wisconsin" de 12 caballos de fuerza. El número de árboles empleados por parcela, repetición y tratamiento se presentan en el cuadro 1.

CUADRO N°1

Número de árboles empleados para probar el Caldo Bordelés, el SR-406 y el Dithane Z-78, contra el P. palmivora. Finca La Lola, Costa Rica. 1951/1954.

Repeticiones	Tratamientos A	B	C	D	E	Totales de Repeticiones
1a.	65	78	76	79	76	374
2a.	75	72	70	66	79	362
3a.	66	76	79	73	73	367
4a.	73	74	79	75	89	390
Totales de Tratamientos	279	300	304	293	317	

Estos estaban sembrados en cuadro a una distancia de 3.65 metros (12 piés) uno de otro y variaban entre 36 y 38 años de edad. La cosecha se hizo cada 14 días, anotándose de cada árbol el número de mazorcas maduras y el número que de éstas estaban infectadas por Phytophthora, pero que el grano era bueno para el mercado.

Aunque el experimento se empezó en septiembre de 1950 solamente se han tomado en cuenta para el análisis estadístico los datos de los últimos 5 semestres. A pesar de que la cosecha se hizo cada 14 días, los datos se analizan por semestres sumando la producción obtenida en cada cosecha. Los datos aquí expuestos corresponden al período comprendido entre el 1° de octubre de 1951 y el 31 de marzo de 1954.

RESULTADOS

En el cuadro 2 se encuentran los datos promedios de producción obtenidos por árbol. Se hizo el análisis estadístico el que se encuentra en el cuadro 3. Se observa que A y C son significativos al nivel del 1% sobre B; A y C son significativos sobre E al nivel del 5%; No hay diferencia significativa entre A, C, y D; Ni tampoco la hay entre D, B, y E.

En el cuadro 4, se encuentran los datos promedios de infección de Phytophthora obtenidos por árbol. El análisis estadístico que se encuentra en el cuadro 5 muestra que A y D son significativos al nivel del 1% sobre los demás tratamientos. C es significativo en contra al nivel del 1% sobre E y B.

CUADRO N°2

Promedio de mazorcas maduras cosechadas por árbol en las parcelas tratadas con Caldo Bordelés, SR-406, y Dithane Z-78, para el combate del P. palmivora. Finca La Lola, Costa Rica. 1951/1954.

Semestre y Tratamientos		Repeticiones 1a.	2a.	3a.	4a.	Total de Semestres
A	1	55.4	52.6	39.1	54.2	201.3
	2	31.8	31.9	35.0	40.7	139.4
	3	47.7	37.2	36.4	47.4	168.7
	4	15.7	13.1	18.7	13.5	61.0
	5	37.5	44.0	49.6	51.7	182.8
Totales de Repeticiones		188.1	178.8	178.8	207.5	753.2
B	1	36.6	21.8	45.3	46.5	150.2
	2	20.3	21.2	24.5	30.9	96.9
	3	18.2	16.3	31.9	28.6	95.0
	4	8.9	4.4	5.6	4.6	23.5
	5	35.7	33.7	43.1	44.1	156.6
Totales de Repeticiones		119.7	97.4	150.4	154.7	522.2
C	1	50.7	67.3	74.0	47.5	239.5
	2	32.1	33.1	26.8	31.8	123.8
	3	39.3	57.5	41.7	36.4	174.9
	4	11.1	13.4	9.5	12.9	46.9
	5	39.1	50.3	41.2	33.5	164.1
Totales de Repeticiones		172.3	221.6	193.2	162.1	749.2
D	1	31.2	59.4	52.2	68.6	211.4
	2	21.1	31.0	30.0	26.1	108.2
	3	22.9	31.7	27.0	36.2	117.8
	4	10.3	13.9	9.1	6.9	40.2
	5	26.7	38.5	36.9	38.4	140.5
Totales de Repeticiones		112.2	174.5	155.2	176.2	618.1
E	1	28.8	59.2	50.4	43.0	181.4
	2	25.9	26.1	43.7	28.2	123.9
	3	21.4	29.6	36.8	14.5	102.3
	4	3.6	7.3	4.7	3.2	18.8
	5	26.4	34.0	33.5	19.5	113.4
Totales de Repeticiones		106.1	156.2	169.1	108.4	539.8

CUADRO N°3

Análisis de variancia de los datos de producción obtenidos con el empleo de tres fungicidas para el combate del *P. palmivora*. Finca La Lola, Costa Rica. 1951/1954.

Fuente de Variación	Grados de Libertad	Suma de Cuadrados	Variancia	F
Total	99	24,950.53		
Subtotal	19	4,579.72		
Repeticiones	3	532.74	177.58	
Tratamientos	4	2,453.71	613.68	4.62[x]
Error (a)	12	1,593.27	132.77	
Semestres	4	16,834.73	4,208.68	108.25[xx]
Interacción: Semestres y Repeticiones	12	348.05	29.00	0.75
Semestres y tratamientos	16	1,321.49	82.59	2.12[x]
Error (b)	48	1,866.54	38.88	

D.M.S. = 158.8 - 5%
222.6 - 1%

CUADRO N°4

Promedios por árbol de mazorcas maduras infectadas de P. palmivora cosechadas en las parcelas tratadas con Caldo Bordelés, SR-406 y Dithane Z-78, para el combate de la enfermedad. Finca La Lola, Costa Rica. 1951/1954.

Semestre y Tratamientos		Repeticiones 1a.	2a.	3a.	4a.	Total de Semestres
	1	0.55	0.41	0.77	0.66	2.39
	2	0.17	0.21	0.30	0.40	1.08
A	3	0.65	0.77	2.00	1.79	5.21
	4	0.14	0.15	0.33	0.25	0.87
	5	0.43	0.76	0.92	1.04	3.15
Totales de Repeticiones		1.94	2.30	4.32	4.14	12.70
	1	2.49	1.53	2.11	2.18	8.31
	2	1.29	0.40	0.78	0.69	3.16
B	3	2.63	2.43	4.02	2.88	11.96
	4	1.01	0.33	0.53	0.26	2.13
	5	2.95	3.07	2.89	3.12	12.03
Totales de Repeticiones		10.37	7.76	10.33	9.13	37.59
	1	5.75	5.40	3.86	3.10	18.11
	2	1.71	2.09	1.14	1.20	6.14
C	3	6.34	6.84	5.75	5.47	24.40
	4	1.39	0.90	0.68	1.29	4.26
	5	3.42	3.16	4.24	2.06	12.88
Totales de Repeticiones		18.61	18.39	15.67	13.12	65.79
	1	1.28	0.94	0.85	1.25	4.32
	2	0.42	0.33	0.29	0.35	1.39
D	3	1.38	1.20	0.85	2.29	5.72
	4	0.25	0.20	0.21	0.09	0.75
	5	0.89	0.83	0.93	0.89	3.54
Totales de Repeticiones		4.22	3.50	3.13	4.87	15.72
	1	1.28	1.28	1.99	1.58	6.13
	2	0.43	0.70	0.99	0.20	2.32
E	3	2.33	1.42	3.08	1.41	8.24
	4	0.24	0.38	0.22	0.16	1.00
	5	1.26	1.54	1.53	0.93	5.26
Totales de Repeticiones		5.54	5.32	7.81	4.28	22.95

CUADRO N°5

Análisis de variancia de los datos de infección obtenidos con el empleo de tres fungicidas para el combate del *Phytophthora palmivora*. Finca La Lola, Costa Rica. 1951/54

Fuente de Variación	Grados de Libertad	Suma de Cuadrados	Variancia	F
Total	99	220.28		
Subtotal	19	101.88		
Repeticiones	3	1.30	0.43	0.83
Tratamientos	4	94.35	23.59	45.43^{xx}
Error (a)	12	6.23	0.52	
Semestres	4	73.69	18.42	92.44^{xx}
Interacción: Semestres y Repeticiones	12	0.90	0.08	0.38
Semestres y Tratamientos	16	34.25	2.14	10.74
Error (b)	48	9.56	0.20	

D.M.S. = 3.56 - 5%
5.00 - 1%

DISCUSION DE LOS RESULTADOS

Del cuadro 2 se obtiene que estadísticamente hay mayor número de mazorcas en los tratamientos con Caldo Bordelés aplicado cada 30 días, y el Dithane Z-78, que en el tratamiento con SR-406 y el Testigo. También se encuentra que no hay diferencia significativa entre el Caldo Bordelés aplicado cada 30 días, el Dithane Z-78 y el Caldo Bordelés aplicado cada 60 días; y que entre el Caldo Bordelés aplicado cada 60 días, el SR-406 y el Testigo no hay diferencia significativa.

Traduciendo estas cifras a porcentajes de aumento en relación con el Testigo se tiene que: el Caldo Bordelés aplicado cada 30 días aumentó la producción en un 39.5 %; el Dithane Z-78, 38.8%; y el Caldo Bordelés aplicado cada 60 días 14.5%.

Del cuadro 4 se obtiene que el Caldo Bordelés en ambos ciclos es significativamente mejor para controlar el Phytophthora que los otros tratamientos; y que en el tratamiento con Dithane Z-78 hay más infección que en cualquiera de los otros tratamientos.

El hecho de haber mayor producción en el tratamiento con Dithane Z-78 que en el Testigo se puede tal vez atribuir a un efecto estimulante de dicho fungicida; pero al encontrar mayor infección en dicho tratamiento indicaría que el Dithane Z-78 no controla el Phythophthora; y que el mayor número de mazorcas infectadas encontradas se debe a las mayores posibilidades que tienen de ser infectadas. Estos datos concuerdan con los encontrados por Thorold (19) en Nigeria.

De los datos de este experimento se concluye que es necesario asperjar las plantaciones de cacao con Caldo Bordelés en períodos de 30 ó 60 días, hasta que se determinen los períodos de mayor incidencia de la enfermedad como lo postula Orellana (15). Además sería indispensable realizar un estudio económico de los costos y métodos de aspersión.

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5RTIC/Doc.21
Fitop./8

LES PRINCIPAUX CRYPTOGAMES OBSERVES SUR THEOBROMA CACAO AU CAMEROUN

Premiere Liste

Jean Grimaldi*

Centre Agronomique du Cameroun

CRYPTOGAMES OBSERVES PRINCIPALEMENT SUR OU A L'INTERIEUR DES CABOSSES

Phytophthora palmivora

Les plus important; a lui seul il est à l'origine d'une perte de récolte évaluée de 20 a 30%.

Trachysphaera fructigena

Assez rare, présent environ sur I/I000 des cabosses atteintes de pourriture.

Botryodiplodia theobromae

Très fréquent, suit souvent l'attaque de Phytophthora palmivora et de Colletotrichum gloeosporioides - mais peut attaquer directement la cabosse - les féves sont immédiatement atteintes et inutilisables.

Colletotrichum gloeosporioides

Très fréquent dans certaines régions (Ambam) où il est la cause de la perte de nombreuses jeunes cabosses de IO a 12 cm. Il peut suivre également l'attaque de Phytophthora palmivora.

Macrophoma Sp.

A l'origine d'une pourriture gris-plombé des cabosses; il n'en a été observé que quelques cas jusqu'a présent.

Pestalozzia Sp.

Très fréquent à l'interieur de cabosses d'apparence saine, mais présentant des traces de piqures.

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* Phytopathologiste Directeur du Laboratoire de Phytopathologie de la Station Experimentale du Centre.

Thielaviopsis ethaceticus

Fréquent à l'interieur de cabosses, d'apparence saine, mais présentant des traces de pqures.

Fusarium sp.

De tres nombreux Fusarium sont observés sur les cabosses mais ne jouent qu'un rôle de saprophytes.

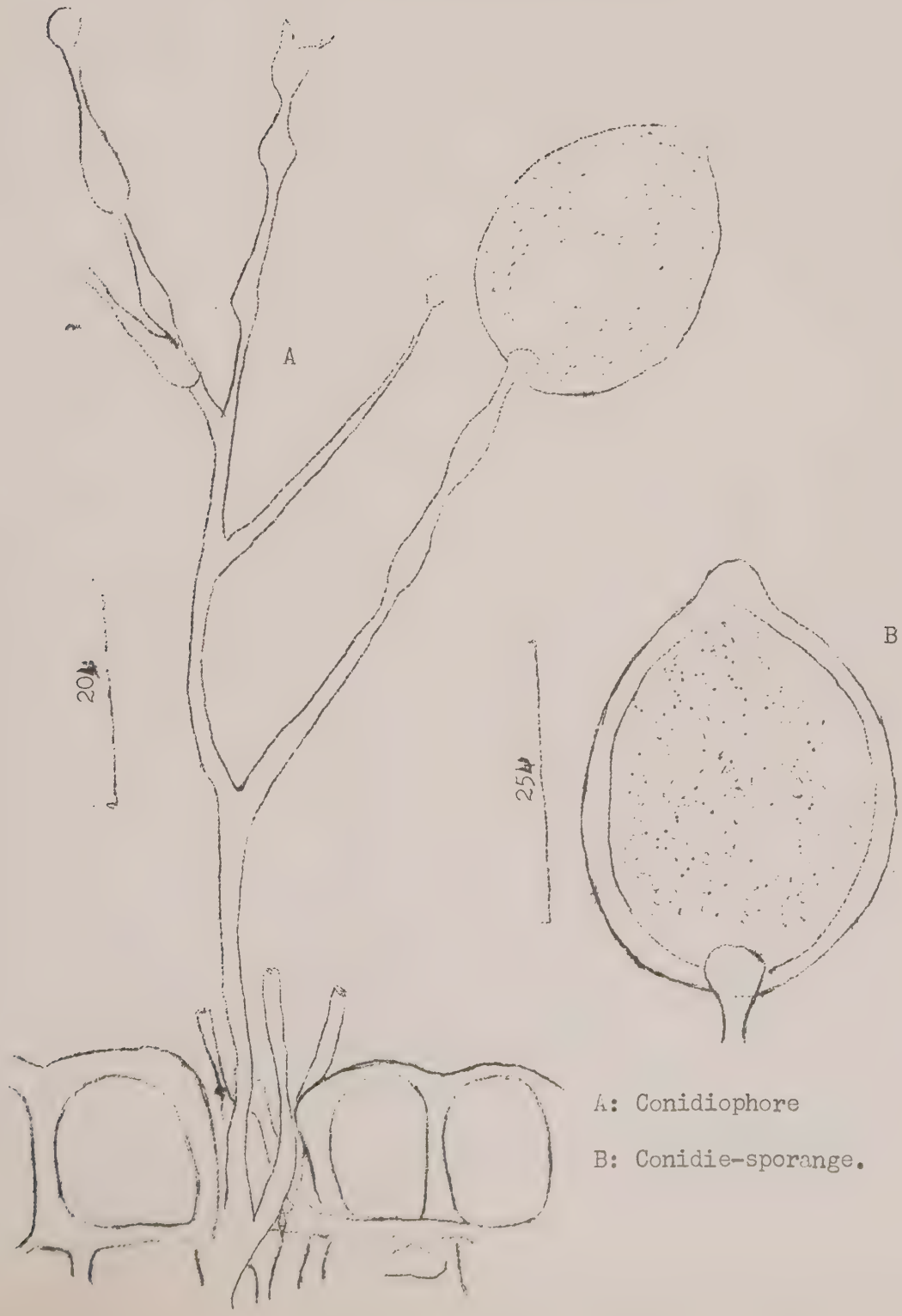
Monilia Sp.

Quelques cabosses sont atteintes par ce Monilia.

Pterula Sp.

Assez fréquent sur de veilles cabosses et sur les plaies de taille.

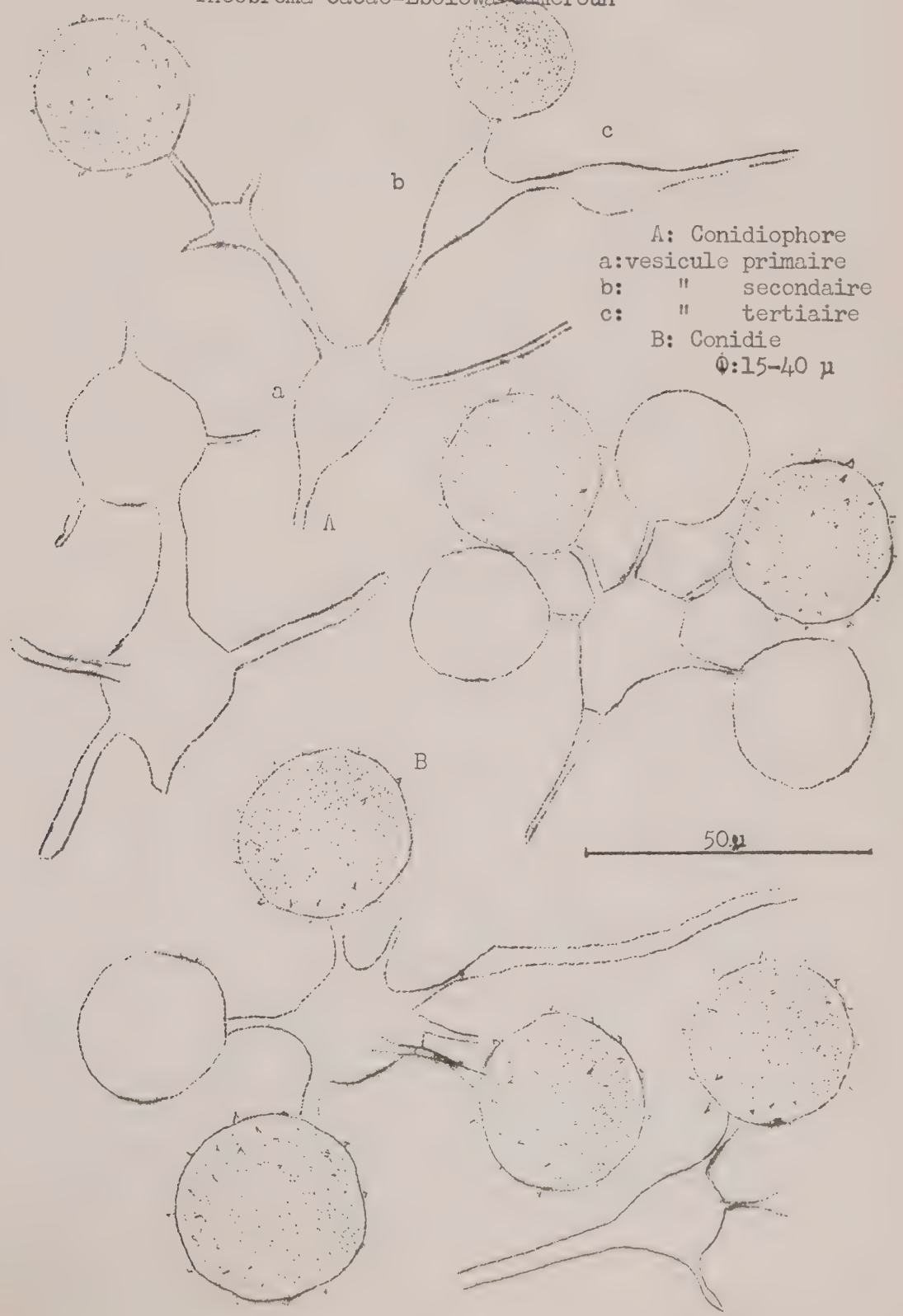
PHYTOPHTHORA PALMIVORA BUTL.
Theobroma cacao-Ebolowa-Cameroun.



A: Conidiophore

B: Conidie-sporange.

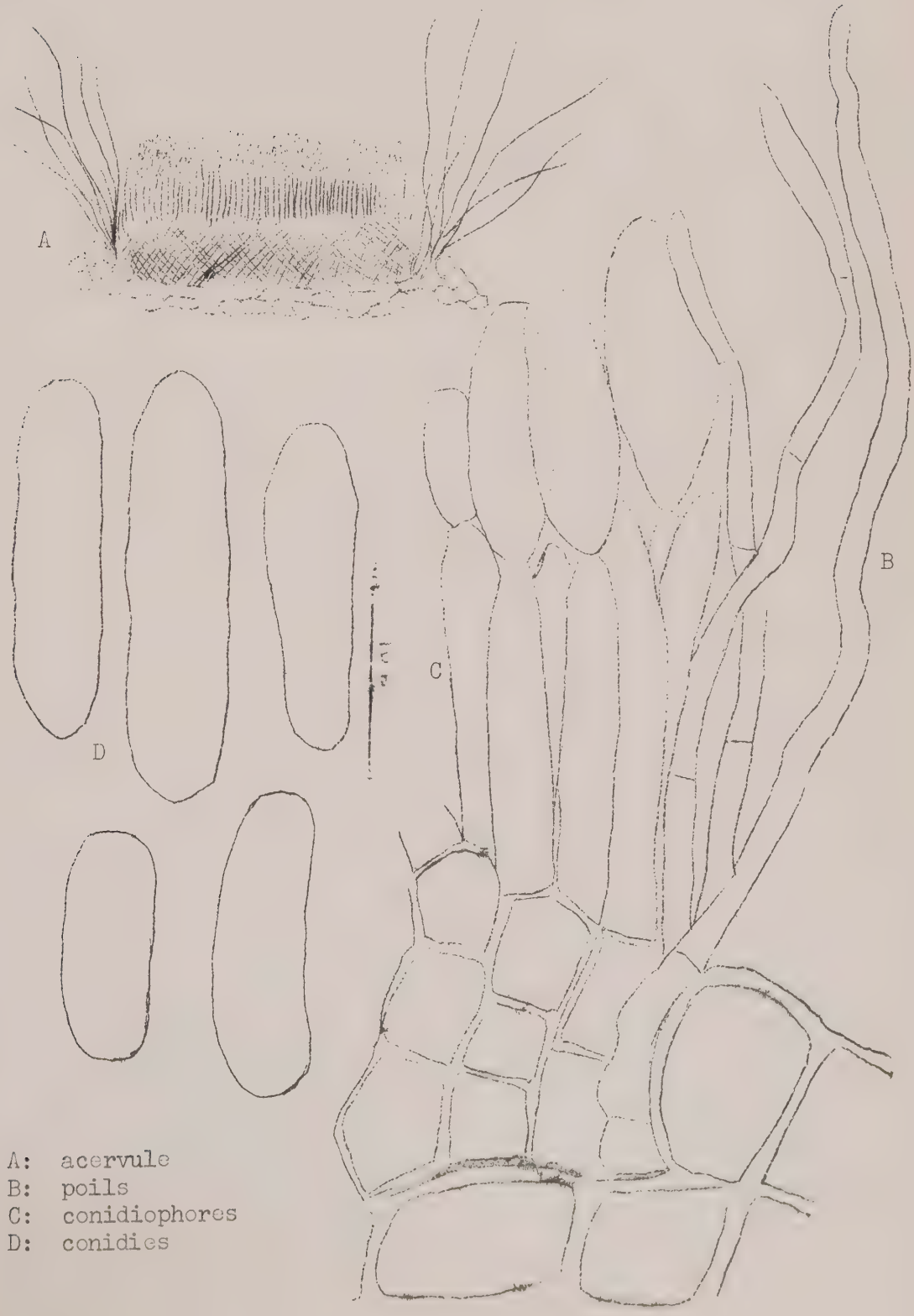
TRACHYSPHAERA FRUCTIGENA Tab et Bont
Theobroma cacao-Ebolowa-Cameroun



BOTRYODIPLODIA THEOBROMAE Pat.
Hab.: Theobroma cacao L. Ebolowa Cameroun

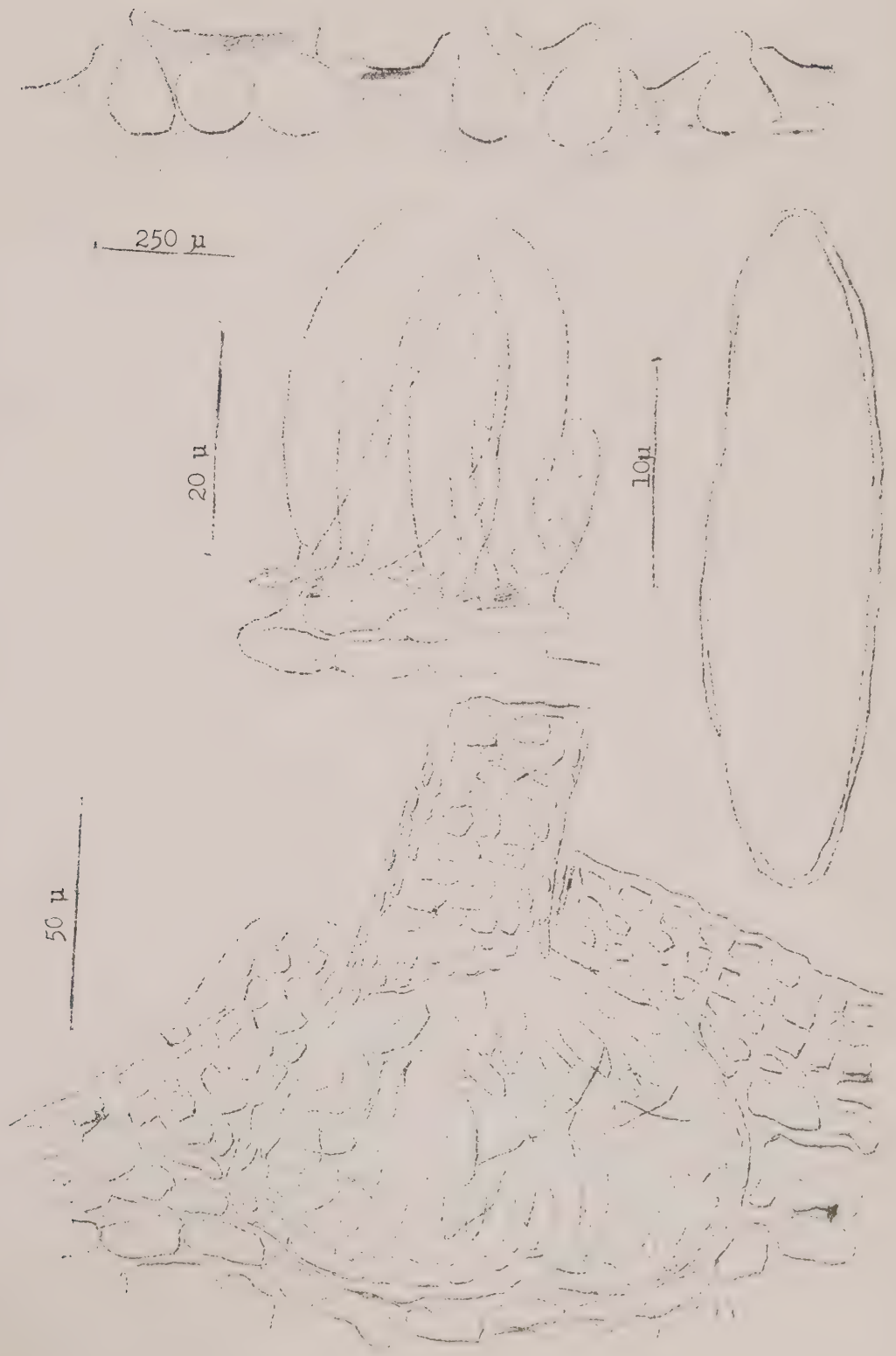
A: Conidie jeune
B: Conidie typique
C: Conidie à 3 closons
(trés rare)

COLLETOTRICHUM GLOEOSPORIOIDES Penz
Hab: Theobroma Cacao L.-Ebolowa-Cameroun

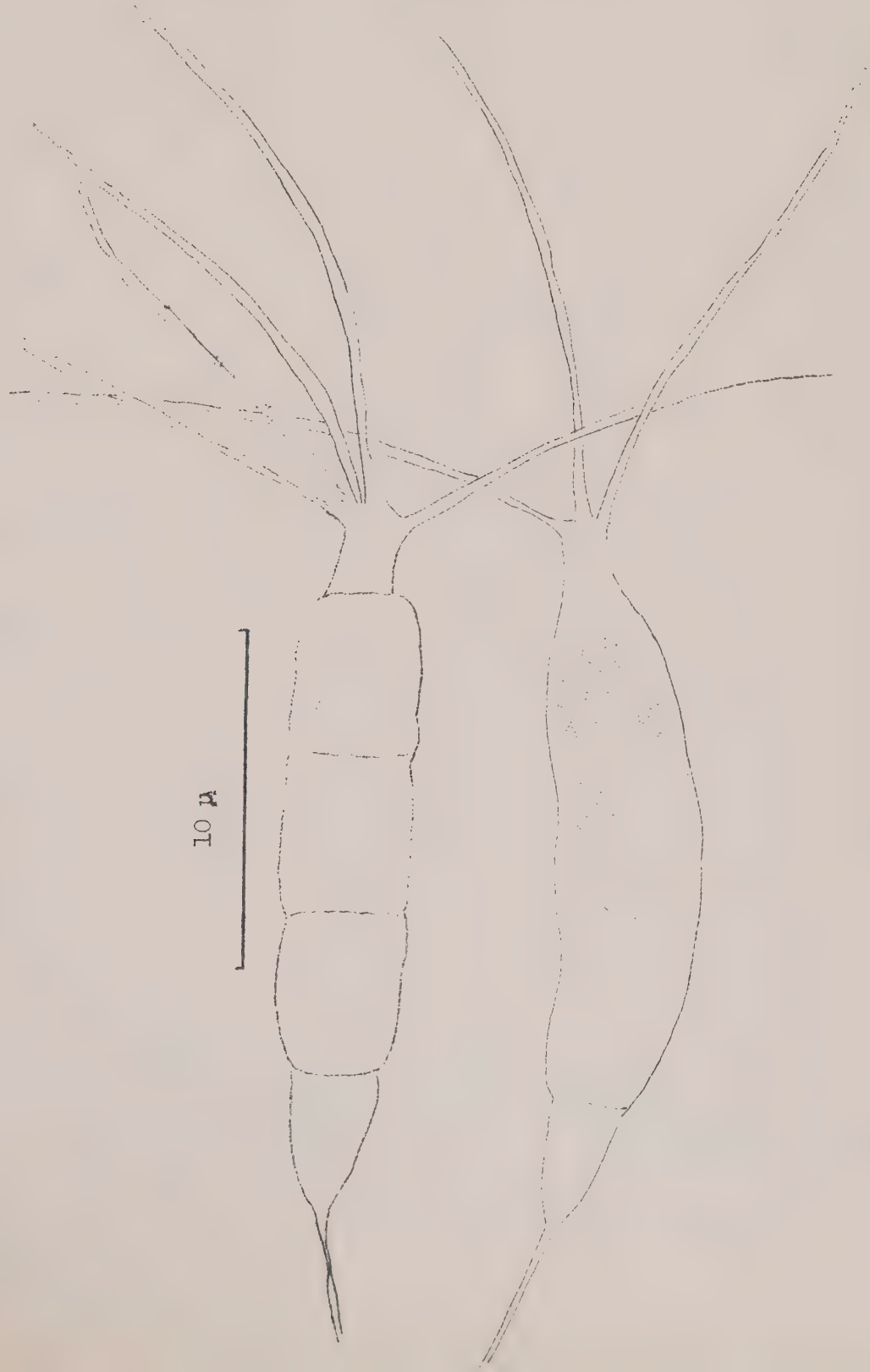


A: acervule
B: poils
C: conidiophores
D: conidies

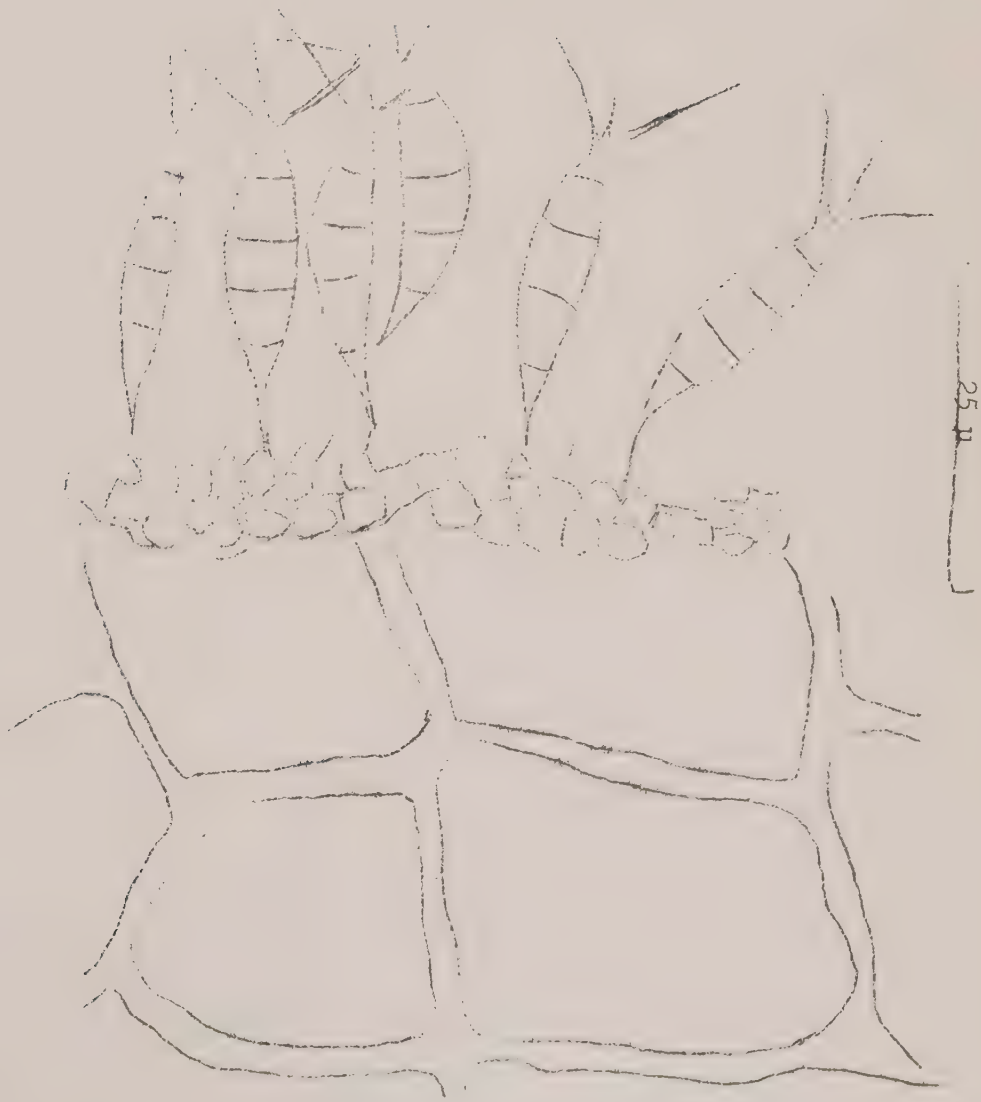
MACROPHOMA SP.
Hab: Theobroma cacao L. Maan Cameroun



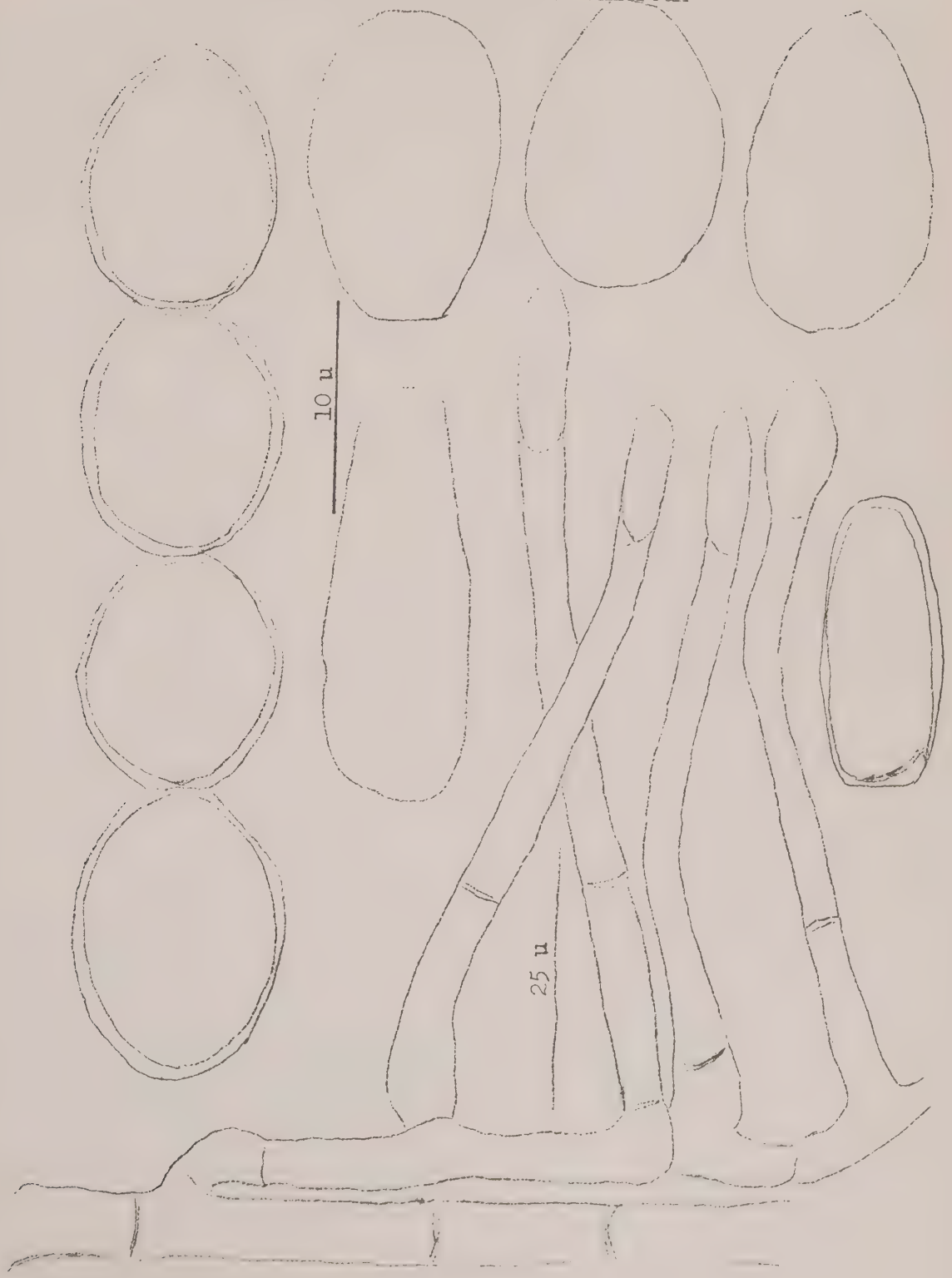
PESTALOZZIA SP.
Hab: Theobroma cacao -Nkoemvone-
Cameroun



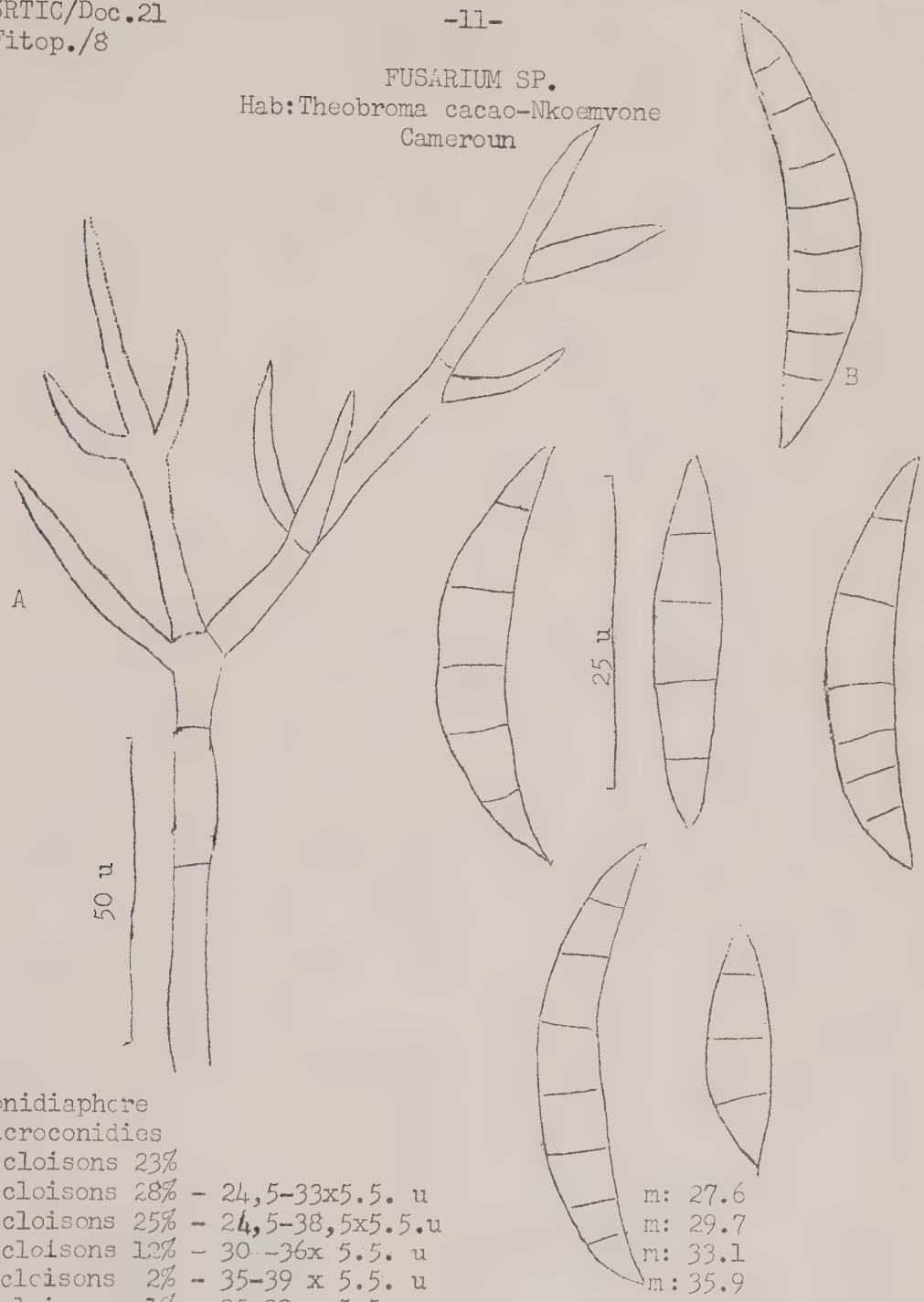
PESTALOZZIA SP.
Hab: Theobroma cacao-Nkoemvone-Cameroun



THIELAVIOPSIS ETHACETICUS Went
Hab: Theobroma cacao-Nkoemvone-Cameroun

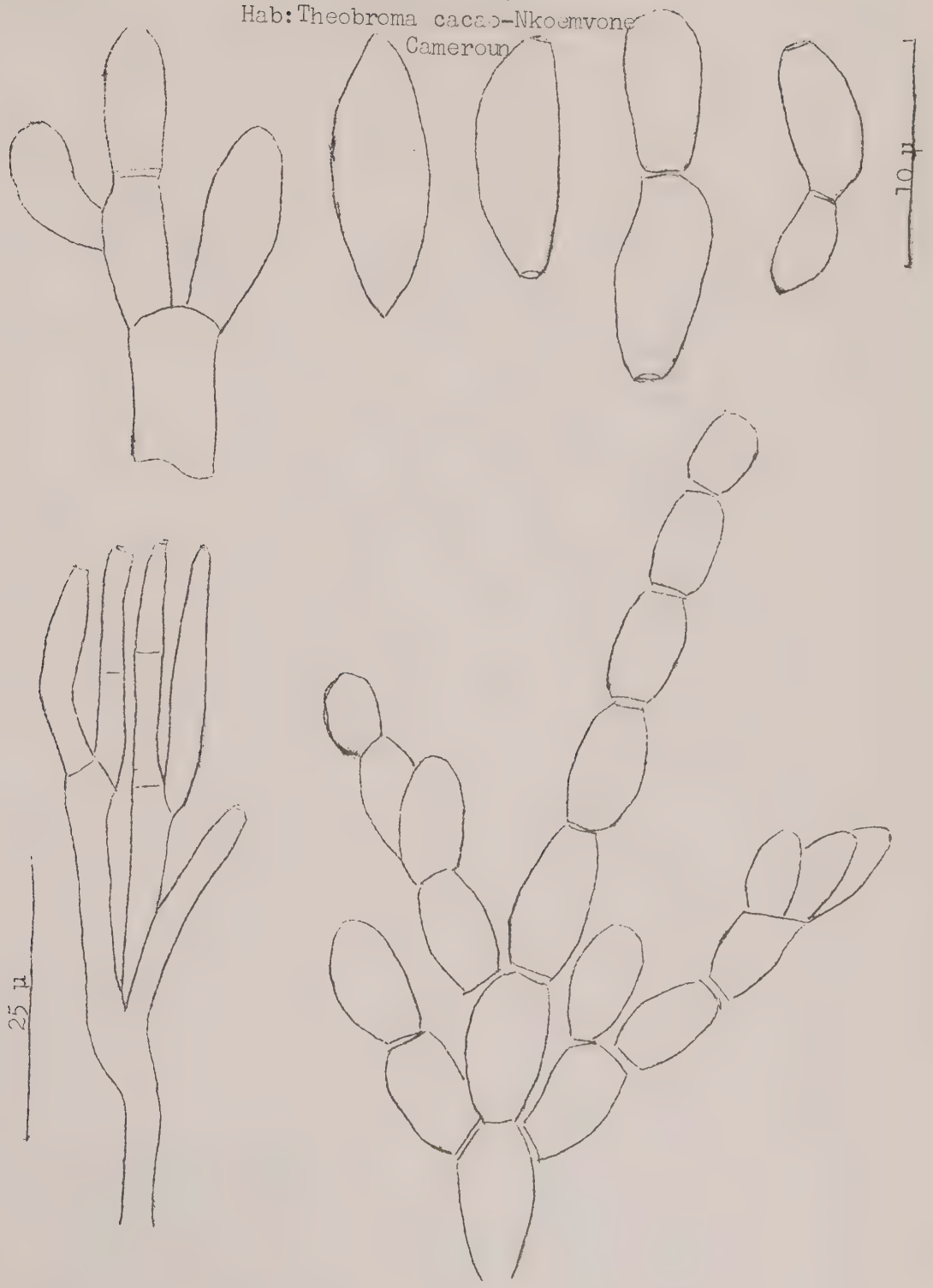


FUSARIUM SP.
Hab: Theobroma cacao-Nkoemvone
Cameroun

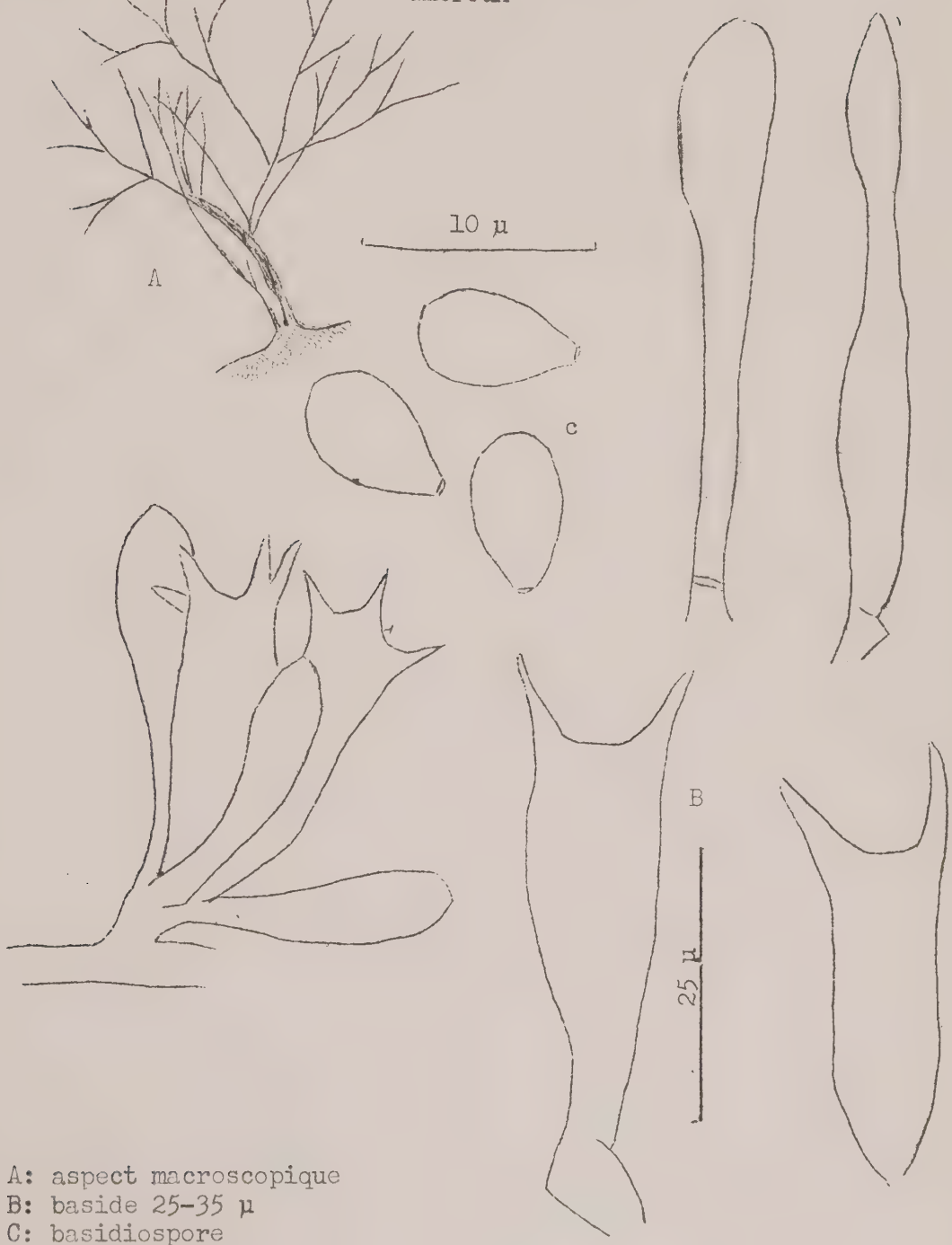


A; Conidiaphore
B: Macroconidies
3 cloisons 23%
4 cloisons 28% - 24,5-33x5.5. u
5 cloisons 25% - 24,5-38,5x5.5.u
6 cloisons 12% - 30 -36x 5.5. u
7 cloisons 2% - 35-39 x 5.5. u
8 cloisons 1% - 35-39 x 5.5. u

MONILIA SP.
Hab: Theobroma cacao-Nkoemvone
Cameroun



PTERULA SP.
Hab: Theobroma cacao -Nkoemvone
Cameroun



A: aspect macroscopique
B: baside 25-35 µ
C: basidiospore
6-9x4-5 µ

CRYPTOGAMES S'ATTAQUANT AUX RACINES ET AU COLLET

Armillariella meliea

Les plus important des pourridiés au Cameroun (95% des cas)

Leptoporus lignosus

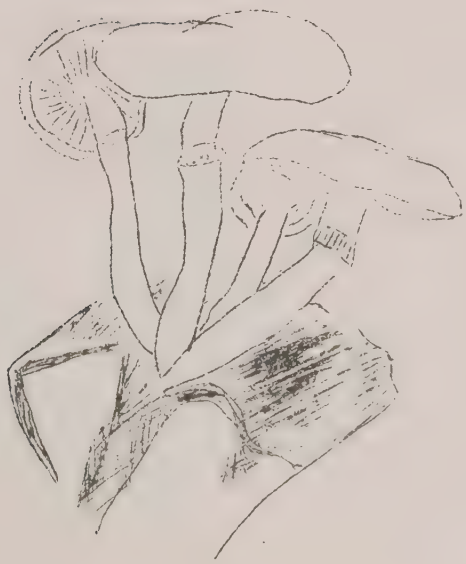
Ustulina maxima

Sphaerostilbe repens

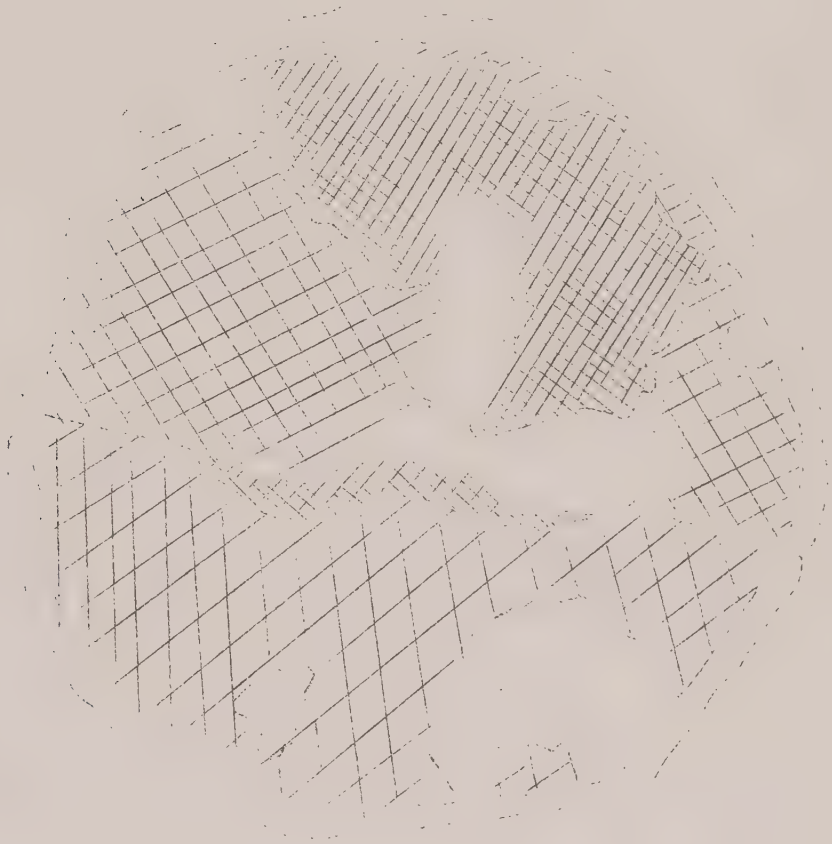
Botryodiplodia theobromae

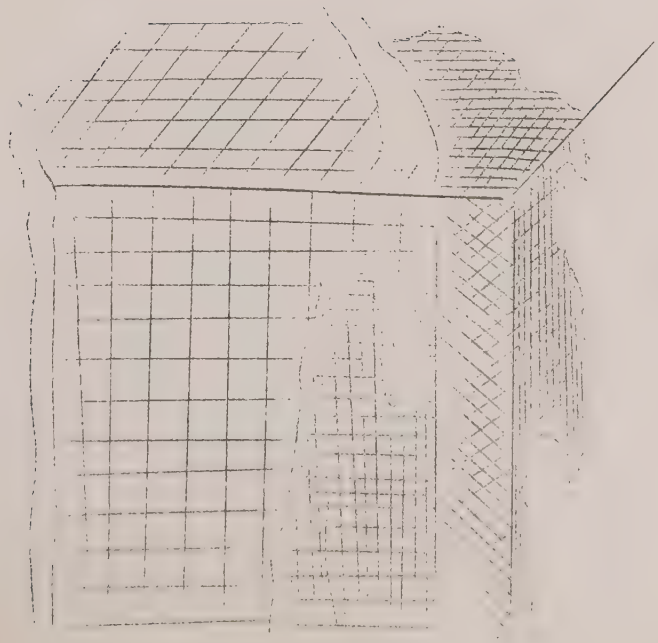
Voir § Cabosses - peut amener la mort d'arbres jeunes par nécrose du collet.

ARMILLARIELLA MELLEA (fr.(Karst.
Hab: Theobroma cacao-Ebolowa-Cameroun

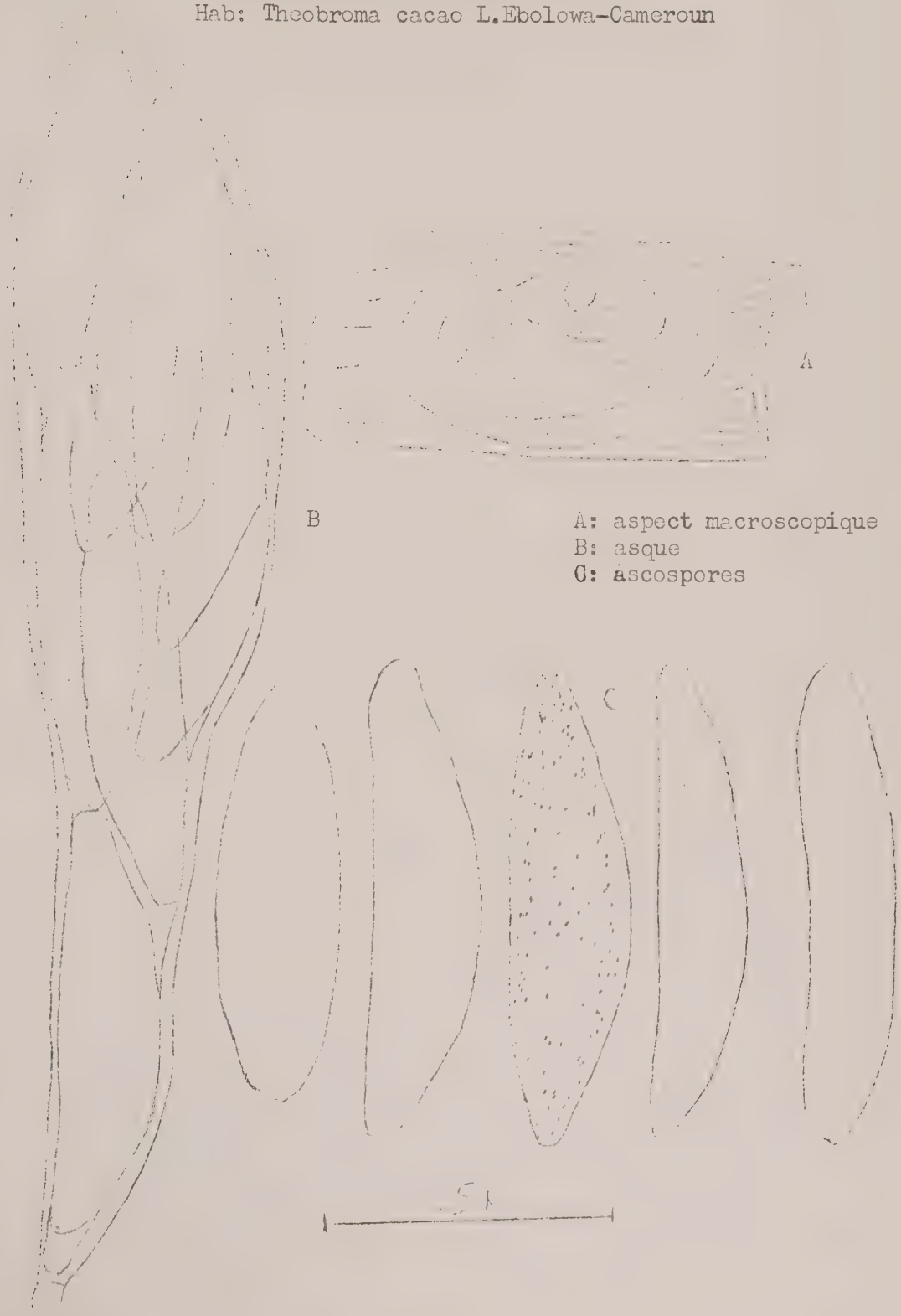


LEPTOPORUS LIGNOSUS (KI.) Iteim et Lat.
Theobroma cacao-Ebolowa, Cameroun



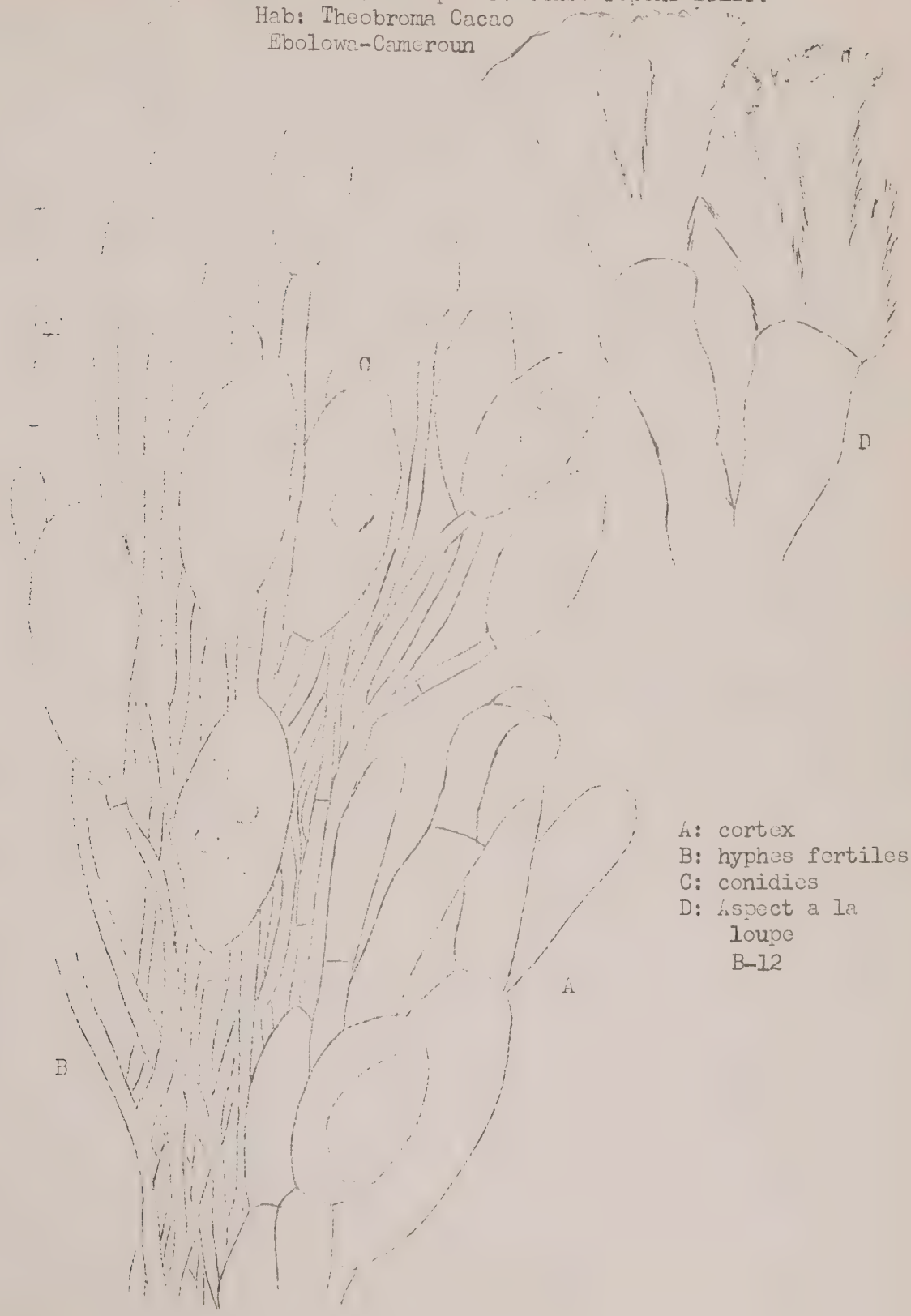


USTULINA MAXIMA (Web.) Wettst.
Hab: Theobroma cacao L.Ebolowa-Cameroun



A: aspect macroscopique
B: asque
C: ascospores

STILBUM SP. F.C. de Sphaerostilbe repens BelBr.
Hab: Theobroma Cacao
Ebolowa-Cameroun



A: cortex
B: hyphes fertiles
C: conidies
D: Aspect a la loupe
B-12

CRYPTOGAMES OBSERVES PRINCIPALEMENT SUR LE TRONC ,

LES BRANCHES ET LES RAMEAUX

Colonectria rigidiuscula
fc Fusarium decemcellulare

Contamine fréquemment les lésions chancreuses causées par la salive phytotoxique de capsides (Salhbergella singularis Hablund).

Marasmius scandens

Agent causal de la maladie du "Fil blanc" fréquent dans les plantations très humides et très ombragées.

Marasmius tricchorizus

Agent causal de la maladie dite du "Fil noir" ou "Crin de cheval" fréquemment associé à Marasmius scandens.

Corticium salmonicolor

Agent causal de "la maladie rose" fréquent dans les plantations très humides et très ombragées.

Nectria ipomoeae

Nectria [illegible]nensis

Nectria cremea

Nectria jungneri

Thyronectria pseudotrichia

Sphaerostilbe repens

Nectriales fréquentes sur les rameaux et les branches.

Eutypella theobromicola

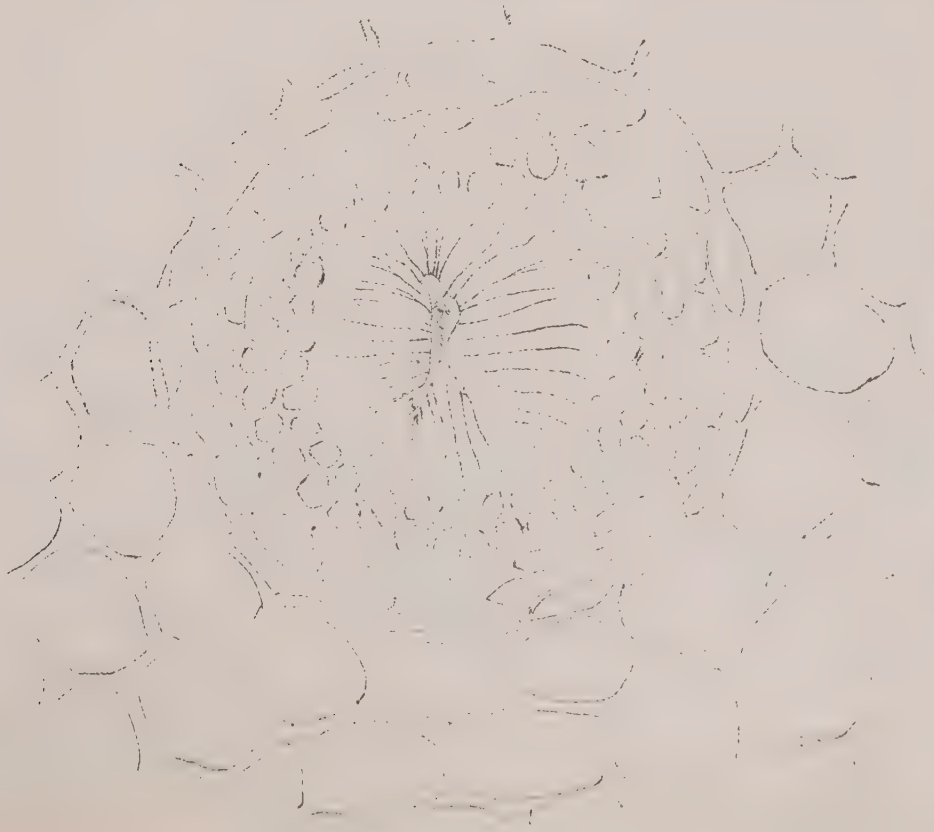
Aurswaldia maxima

Trybilidiella ruffula

CALONECTRIA RIGIDIUSCULA
(B. et Br) Sacc.
Hab: Theobroma cacao

200 µ

En coupe:
Stroma et périthèces

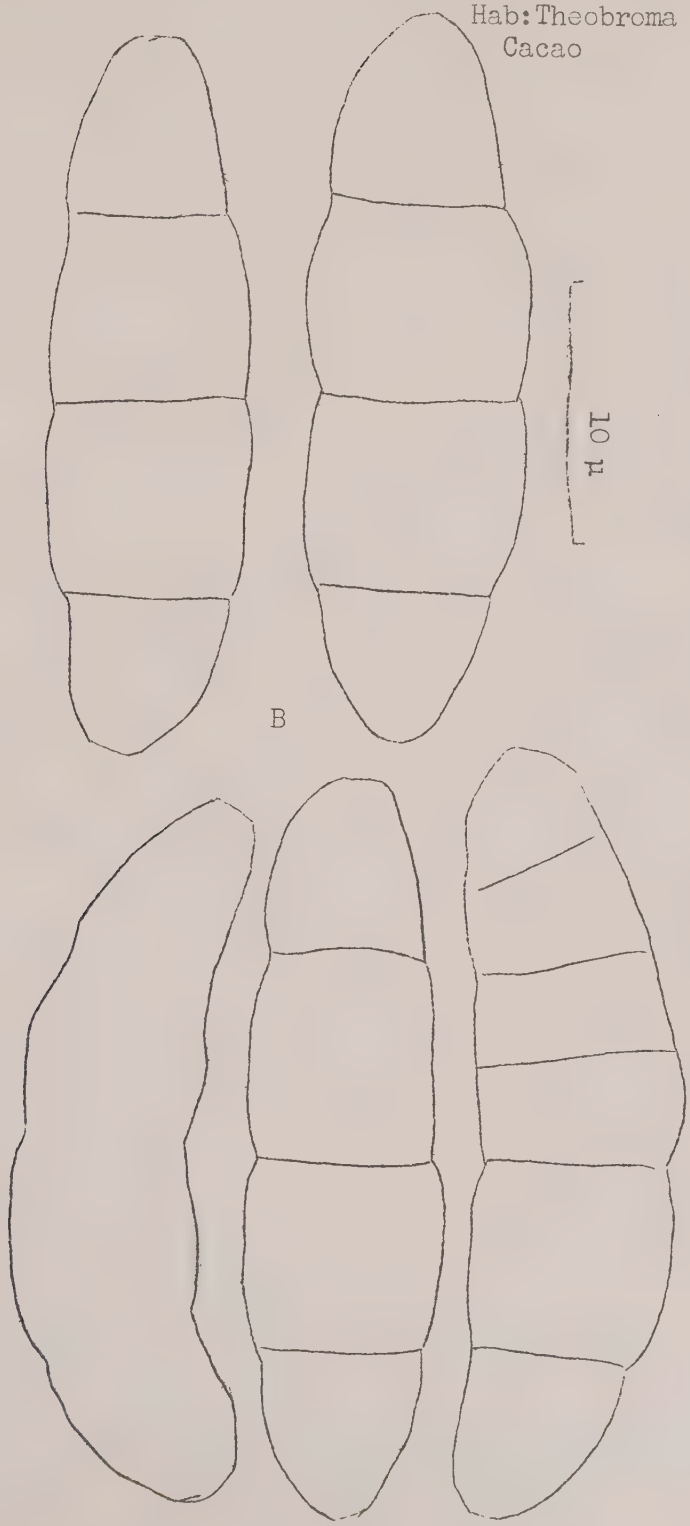


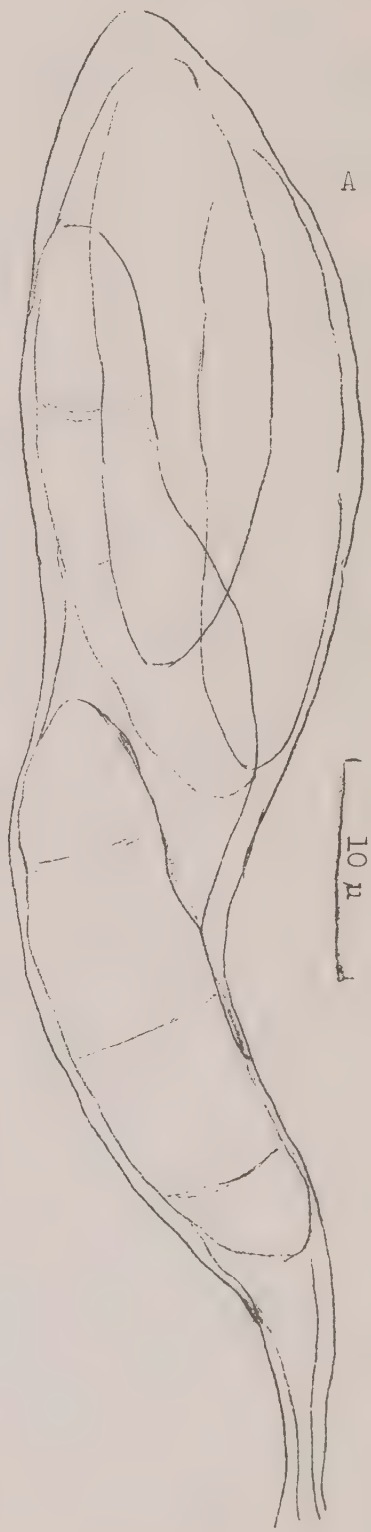
50 µ

Détails de l'ouverture
d'un périthèce

CALONECTRIA RIGIDIUSCULA
(B.et Br.)Sacc.
Hab:Theobroma
Cacao

A: Asque 60-75 x10-13 µ





B: Ascospores 23-29x7-8.5 µ

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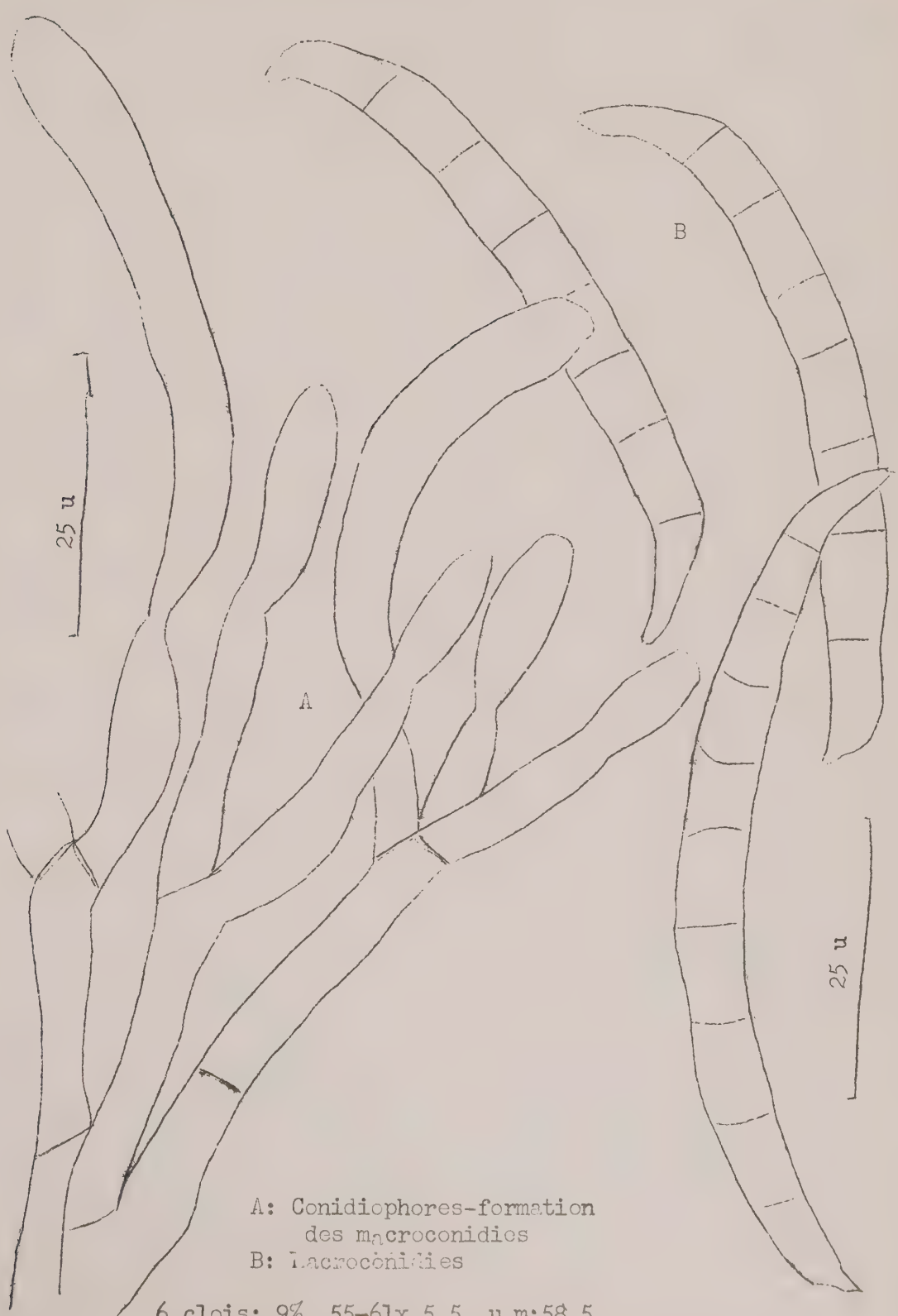
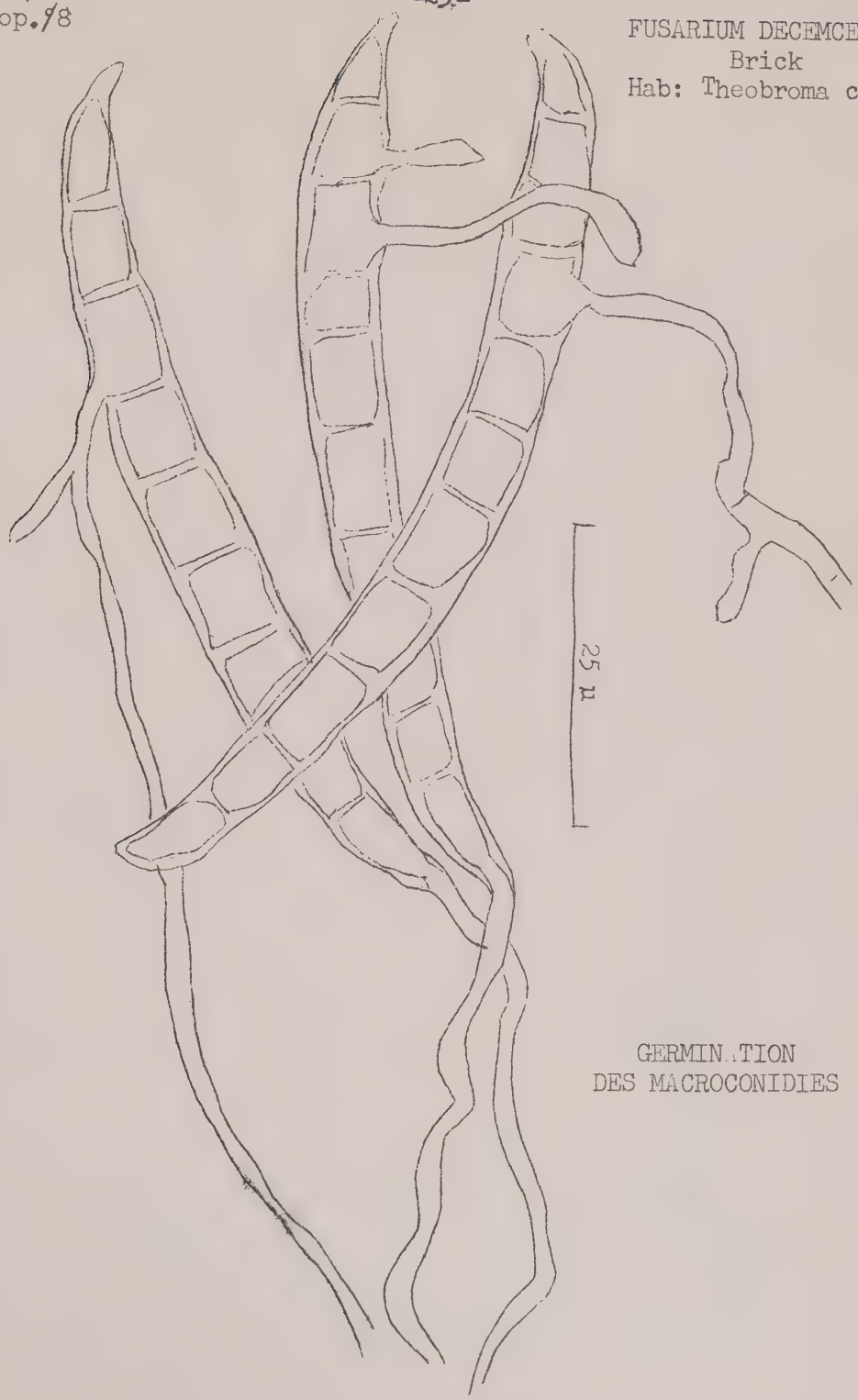
FUSARIUM DECEMCELLULARE BRICK.
Hab: Theobroma cacao -Nkoemvone-Cameroun



A: Conidiophores-formation des macroconidies
B: Macroconidies

6 clois: 9% 55-61x 5.5. u m:58.5
7 clois:25% 58-71x5.5. u m:64
8 clois:34% 58-75x 5.5. u m:68.8
9 clois:32% 62-80x 5.5. u m:73.2

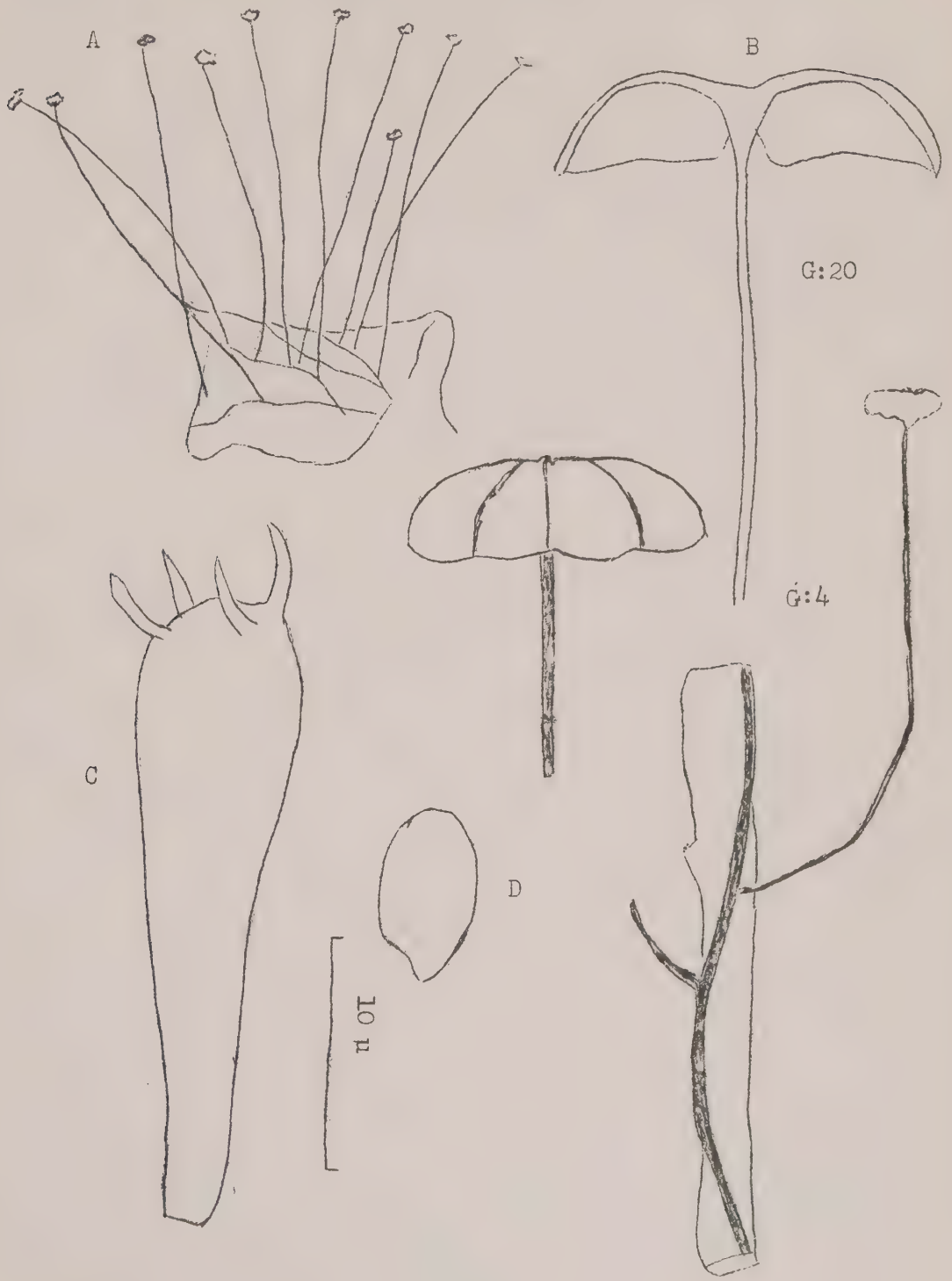
FUSARIUM DECEMCELLULARE
Brick
Hab: Theobroma cacao



GERMIN..TION
DES MACROCONIDIES

MARASMIUS TRICHORRHIZUS Speg.

Hab: Theobroma cacao-Nkoemvone-Cameroun

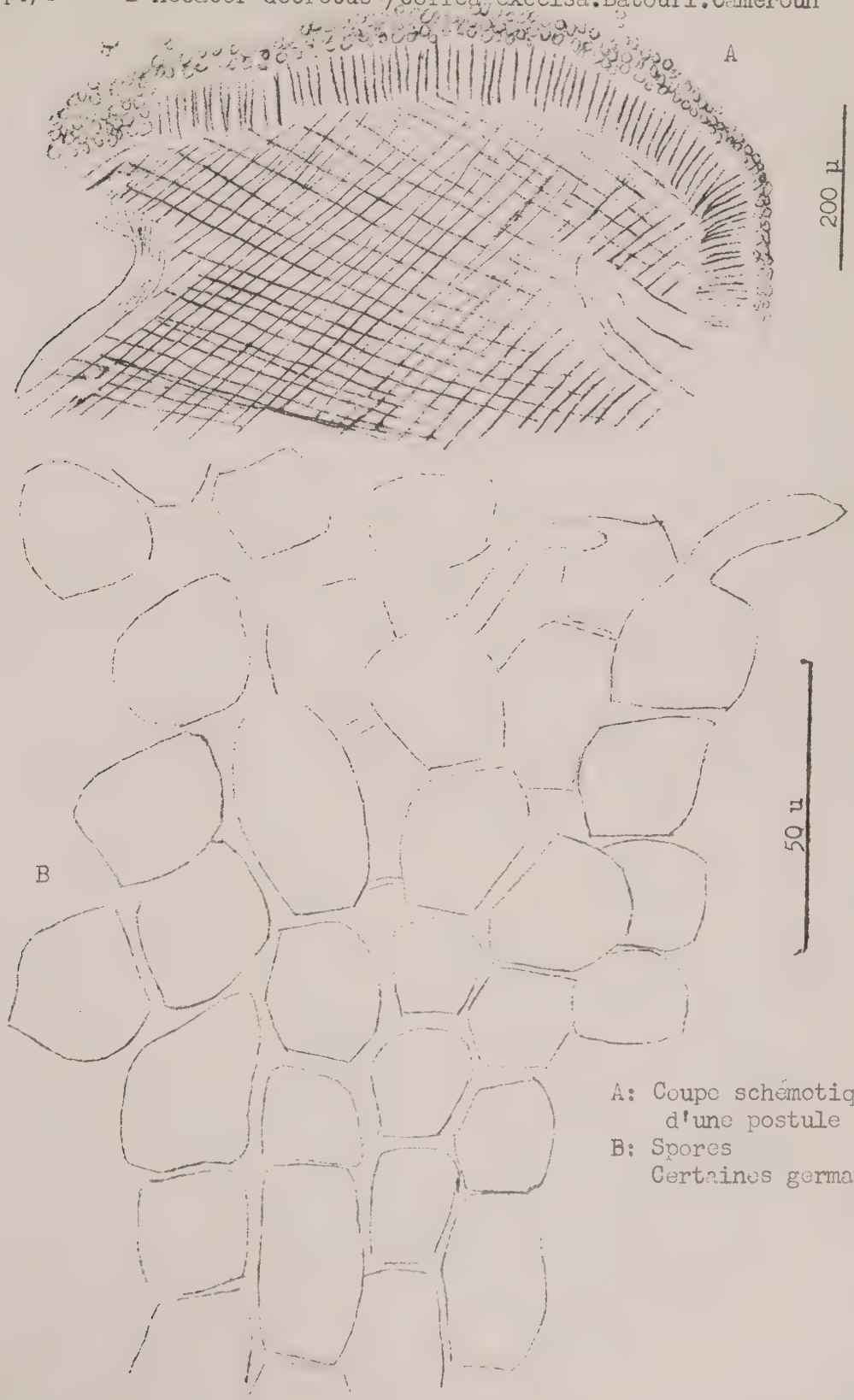


A, B: Carpophores

C: baside
12-18x4-6 µ

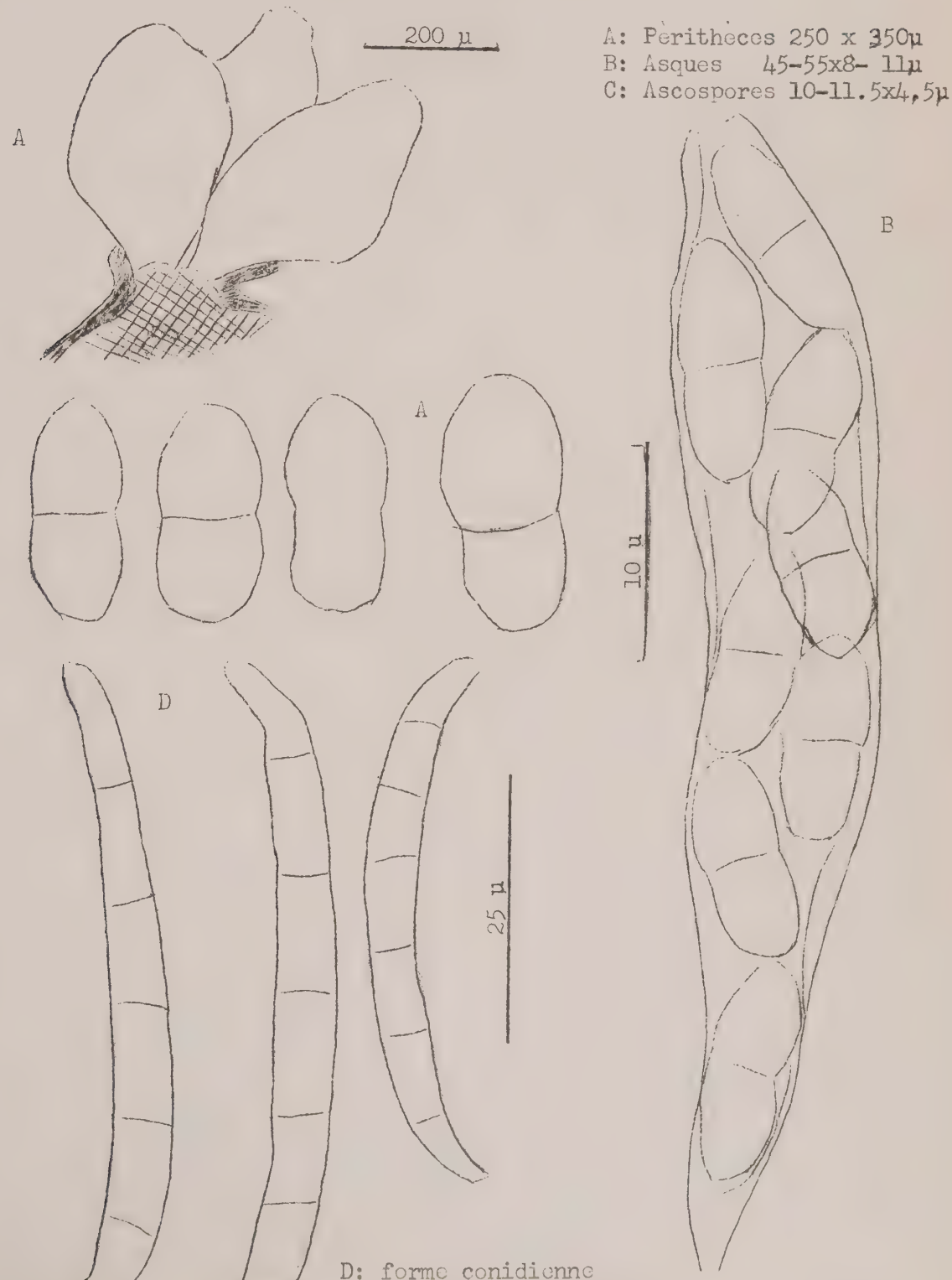
D: basidiospore
5-10x3-5 µ

5RTIC/Doc.21 CORTICIUM SALMONICOLOR B.et Br.
Fitop./8 E necator decretus-/Coffea excelsa.Batouri.Cameroun

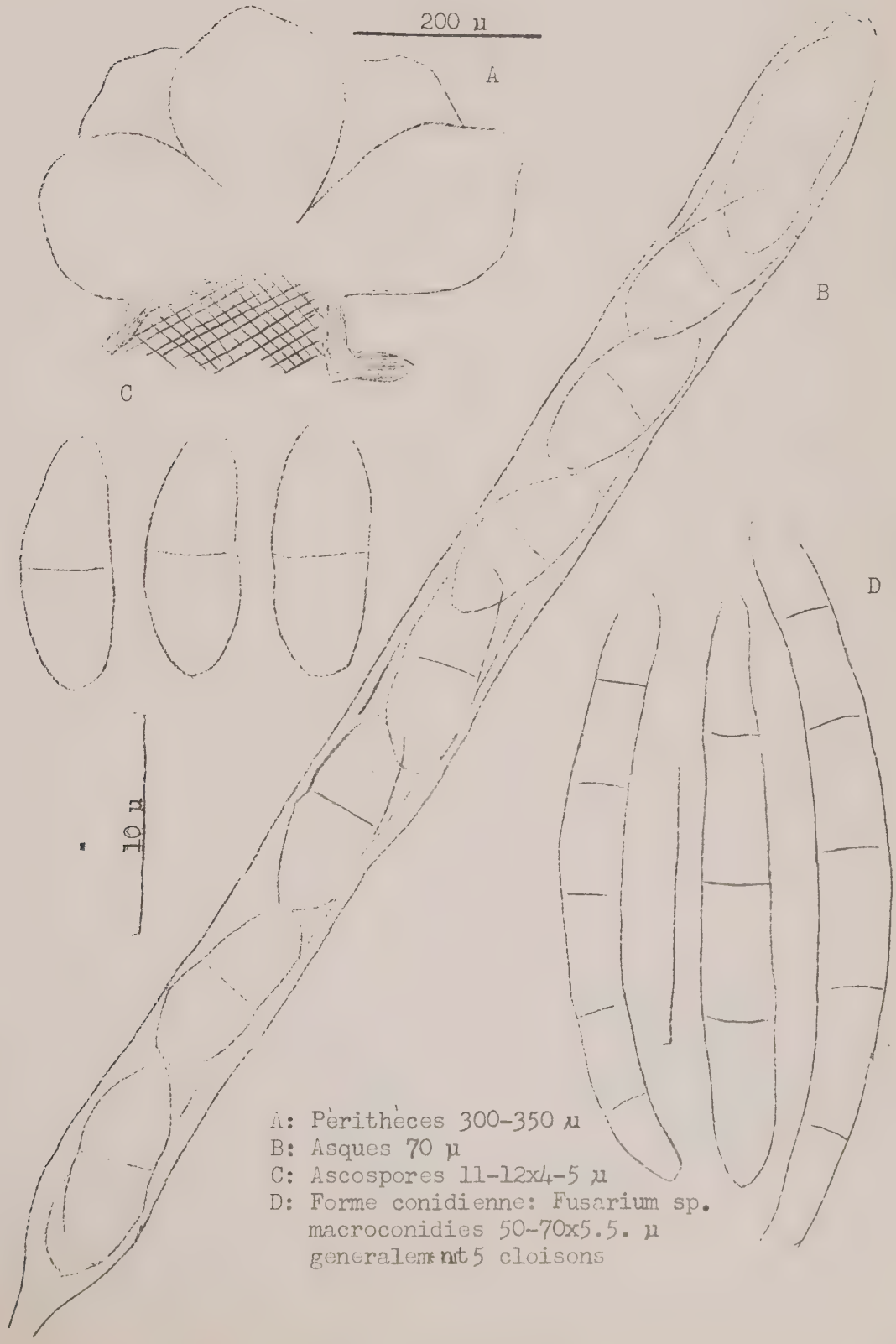


A: Coupe schématique d'une postule
B: Spores
Certaines germant

NECTRIA IPOMOEDE HALS.
Hab: Theobroma cacao-Nkoemvone-Cameroun

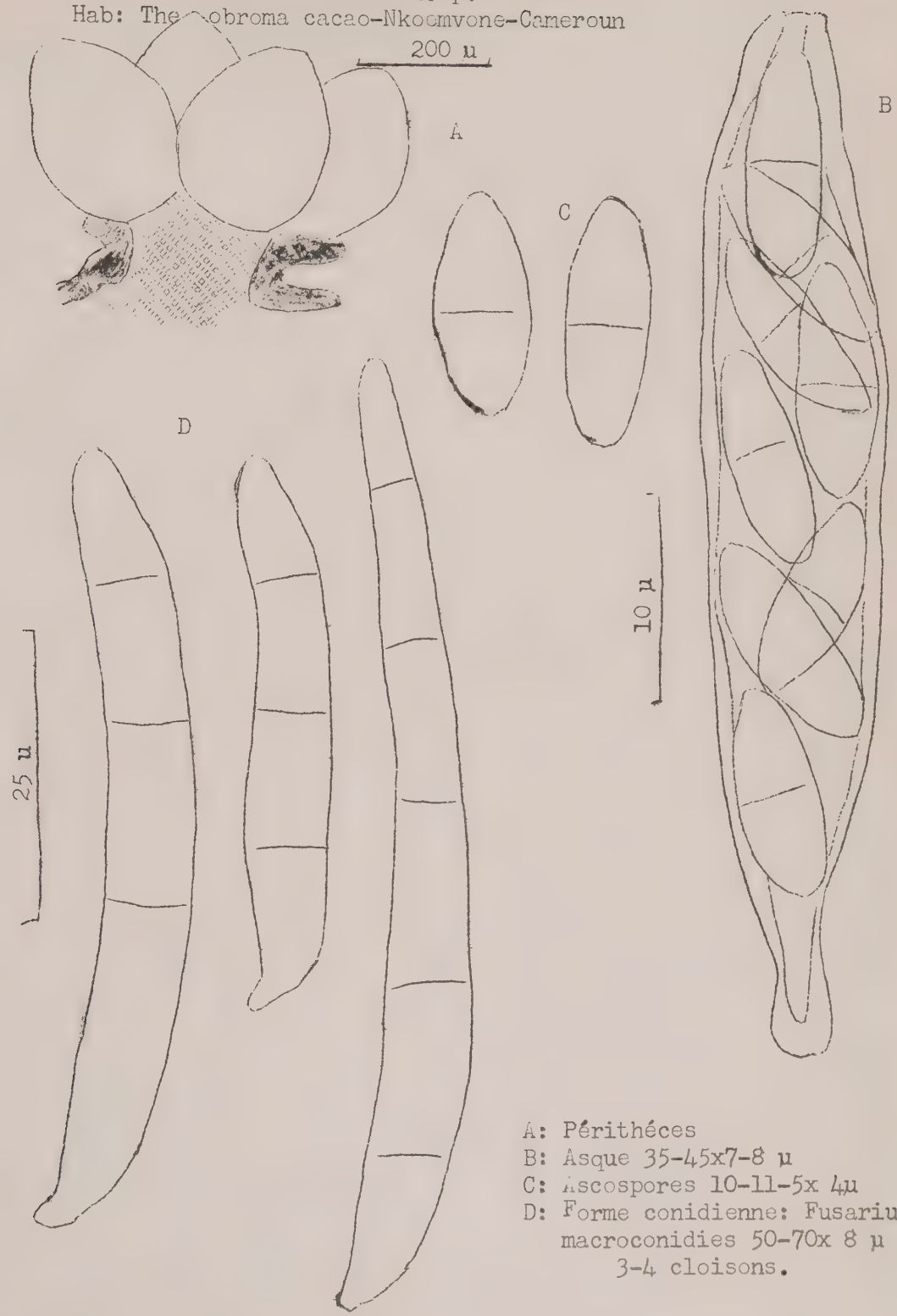


NECTRIA NKOEMVONENSIS n.sp.
Hab: Theobroma cacao-Nkoemvone-Cameroun



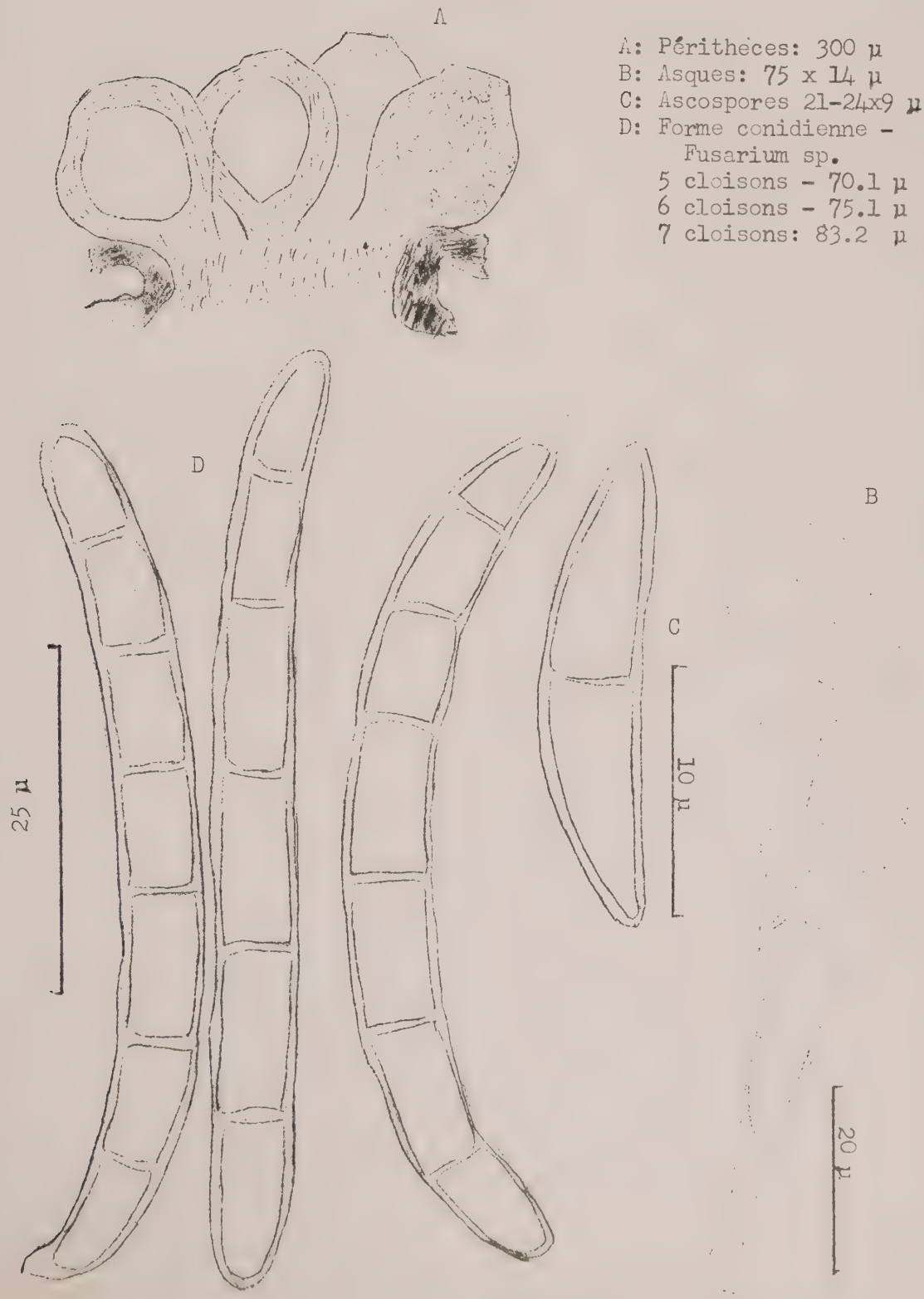
A: Périthèces 300-350 µ
B: Asques 70 µ
C: Ascospores 11-12x4-5 µ
D: Forme conidienne: Fusarium sp.
macroconidies 50-70x5.5. µ
generalement 5 cloisons

NECTRIA CREMEA n.sp.
Hab: Theobroma cacao-Nkoemvone-Cameroun



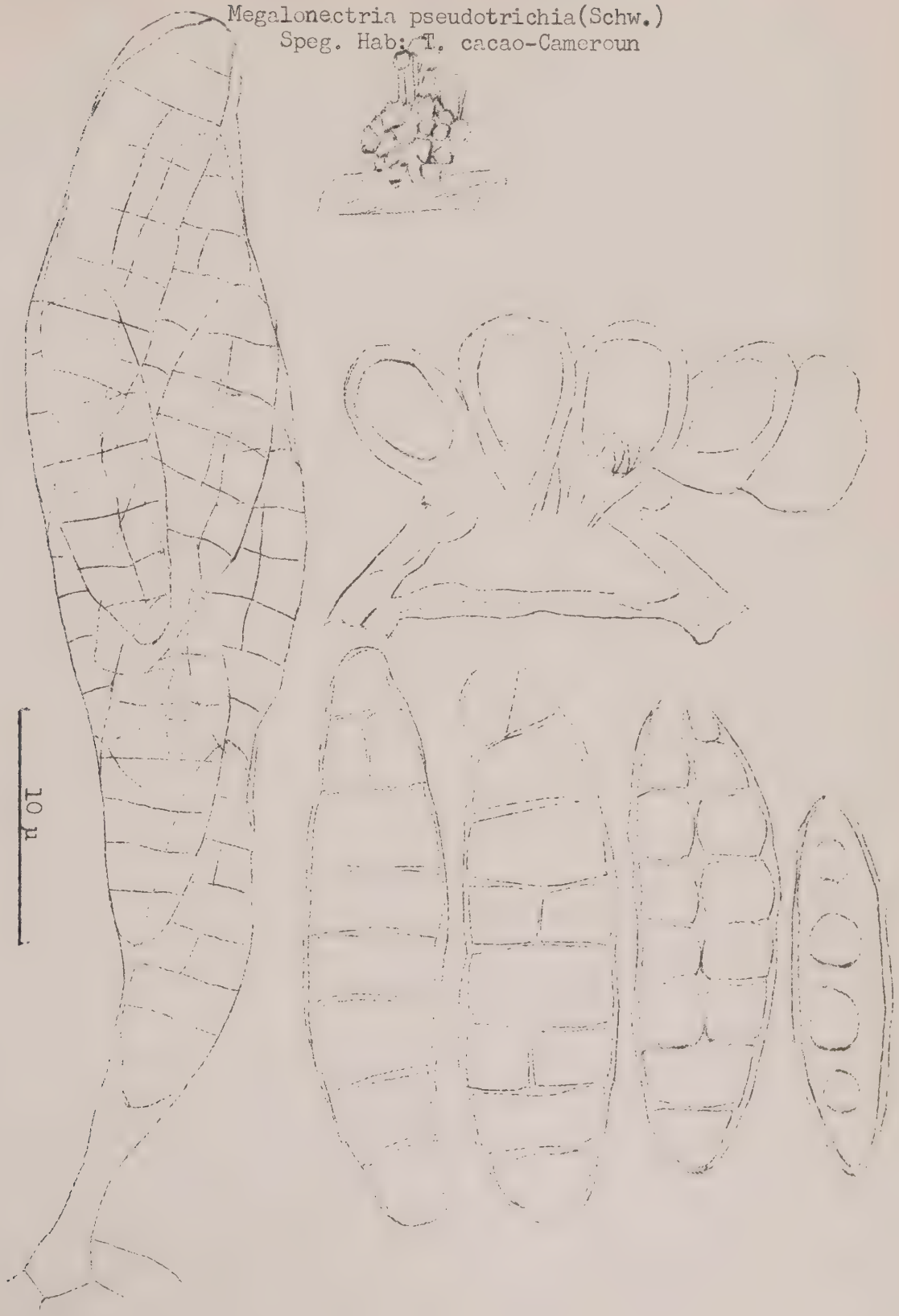
A: Périthéces
B: Asque 35-45x7-8 µ
C: Ascospores 10-11-5x 4µ
D: Forme conidienne: Fusarium
macroconidies 50-70x 8 µ
3-4 cloisons.

NECTRIA JUNGNERI P.Henn
Hab: Theobroma Cacao L. Ebolowa-Cameroun



A: Périthèces: 300 µ
B: Asques: 75 x 14 µ
C: Ascospores 21-24x9 µ
D: Forme conidienne - Fusarium sp.
5 cloisons - 70.1 µ
6 cloisons - 75.1 µ
7 cloisons: 83.2 µ

THYRONECTRIA PSEUDOTRICHIA
Megalonectria pseudotrichia(Schw.)
Speg. Hab: T. cacao-Cameroun



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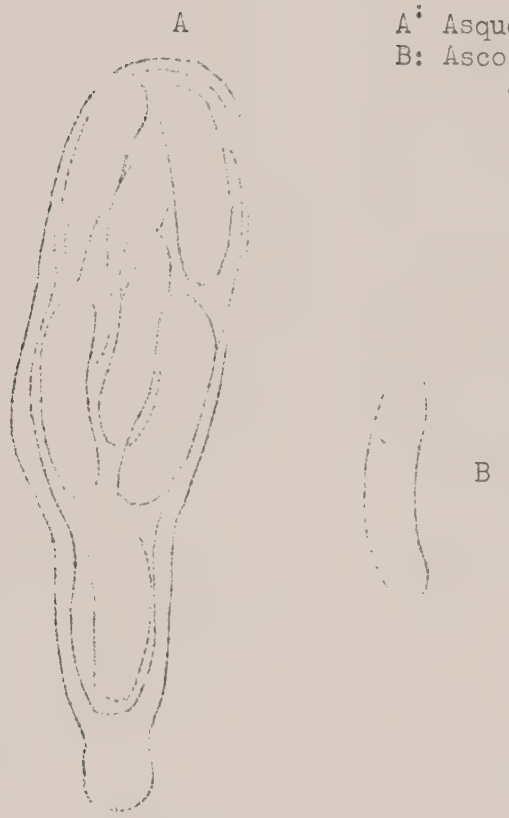
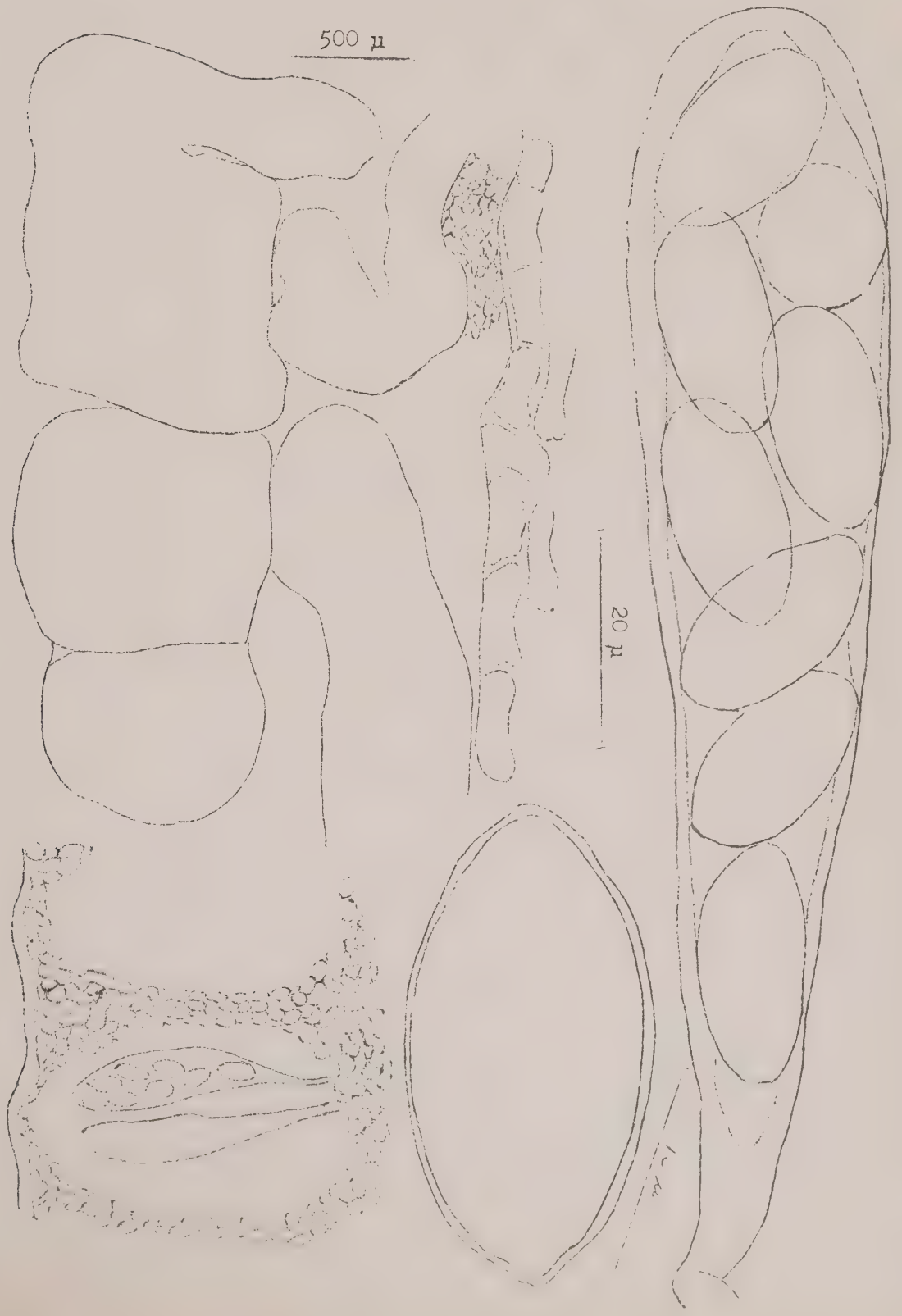
EUTYPELLA THEOBROMICOLA Wakef.

Hab: Theobroma cacao L. Ebolowa.Cameroun



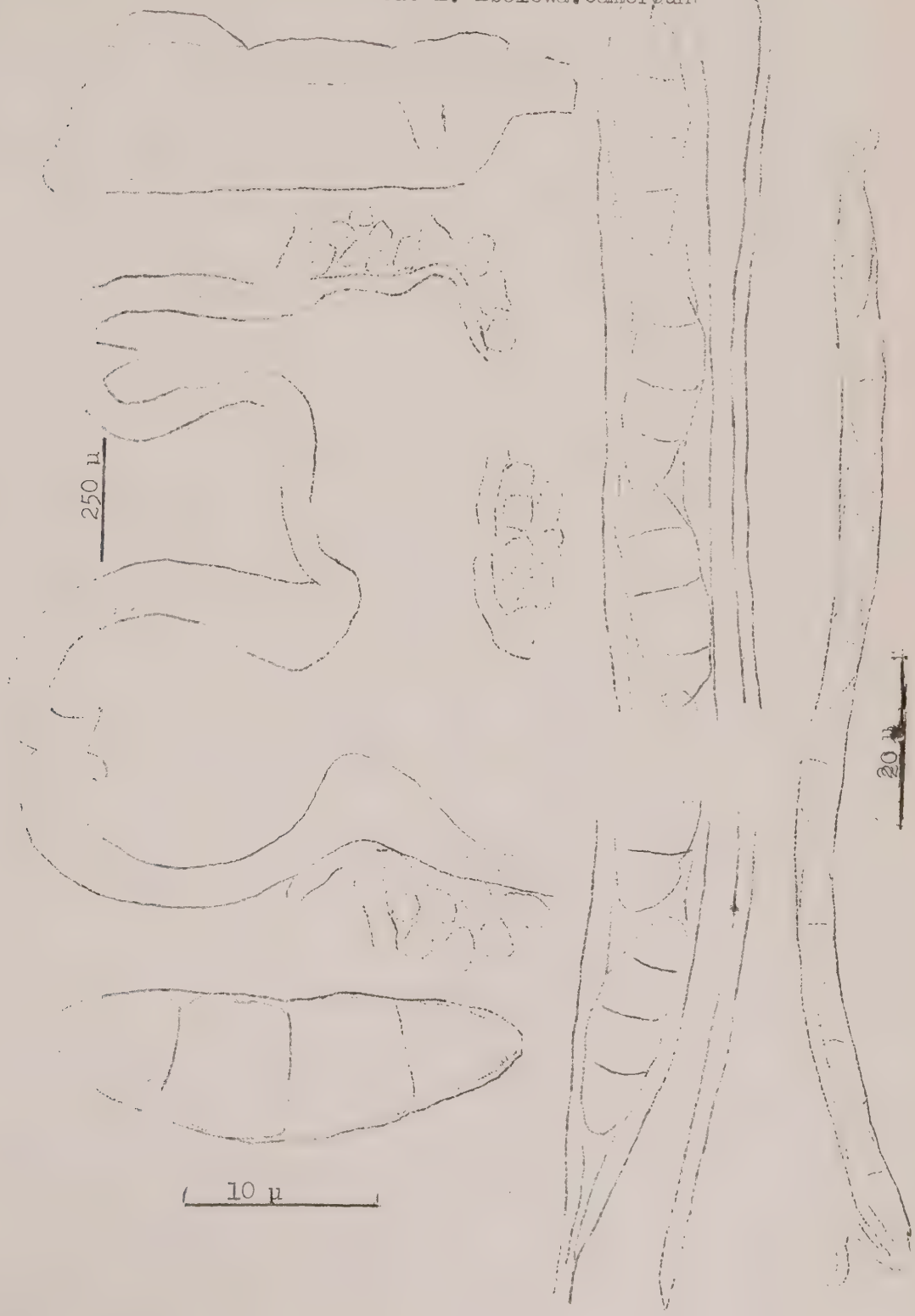
A: Asque 22.25x4.5 µ
B: Ascospores
6-7 x 2 µ

AUERSWALDIA MAXIMA
Hab: Theobroma cacao L. Ebolowa-Cameroun



TRYBLIDIELLA RUFFULA

Hab: Theobroma cacao L. Ebolowa.Cameroun



CRYPTOGAMES OBSERVES SUR LES FEUILLES

Marasmius scandens

Maladie "du fil blanc"

Marasmius tricchorizus

Maladie "du fil noir"

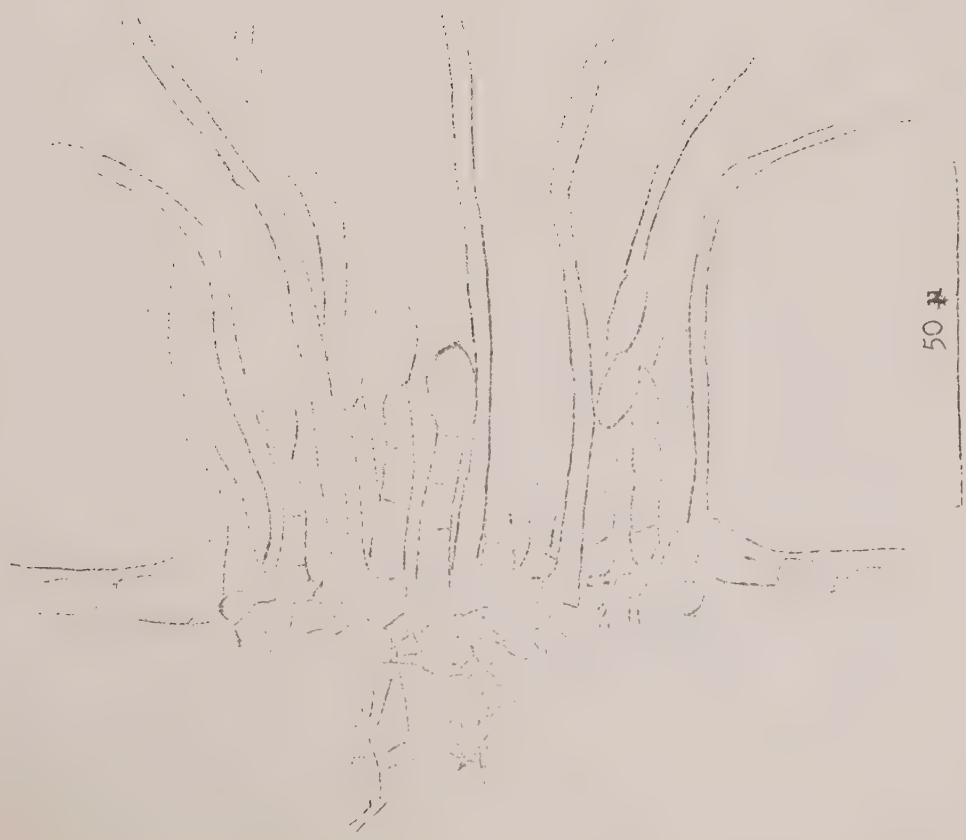
Colletotrichum sp.

ALGUE OBSERVEE SUR LES FEUILLES

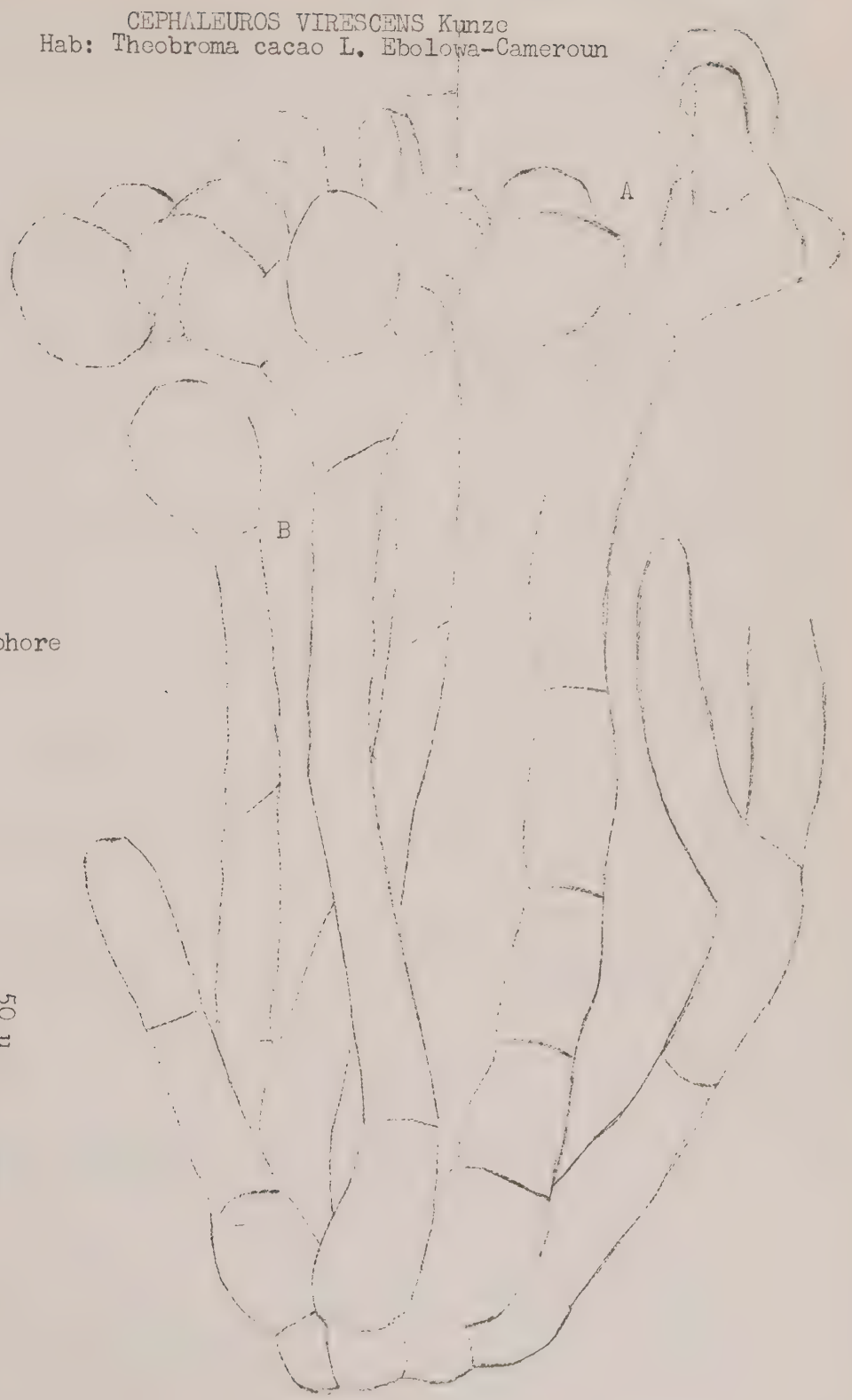
Cephaleuros virecens

(fausse rouille) assez rare

COLLETOTRICHUM SP.
Hab: Theobroma cacao-Nkoemvone-Cameroun



CEPHALEUROS VIRESCENS Kunze
Hab: Theobroma cacao L. Ebolowa-Cameroun



A: sporange
B: sporangiophore

3 July 54
Cacao -218-54

INSECTES DANGEREUX AUX CULTURES DE CACAOYERS DU CAMEROUN

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Les parasites les plus dangereux sont les capsides. Trois especes se rencontrent un peu partout sur les arbres.

SALHBERGELLA SINGULARIS Haglund. punaise mouchetée.

DISTANTIELLA THEOBROMAE Dist. punaise noire.

HELOPELTIS BERGROTHI "moustique" du cacaoyer.

SALHBERGELLA SINGULARIS est de loin l'espèce la plus dommageable aux cultures. Elle existe pratiquement sur toutes les plantations et à travers tout le territoire.

Cette punaise en association avec des champignons est responsable d'une grave maladie "Le dessechement des extrémités du cacaoyer".

Cette affection sevit intensement dans certains cantons y amenant la stérilité à peu près complète des arbres.

Ailleurs les signes de la maladie sont moins prononcés mais partout on observe des taches de die back d'une manière très fréquente.

DISTANTIELLA THEOBROMAE Dist. Beaucoup plus rare que l'espèce précedente, ce capside se rencontre surtout sur plantations jeunes. La station de cacaoyers de Nkoémvone en particulier a eu à souffrir de l'action de ce parasite.

Les manifestations de la piqûre de deux espèces de capsides sont les mêmes: noircissement des extrémités puis dessechement.

HELOPELTIS BERGROTHI. Ces capsides sont très largement répandus mais leurs dégats visibles surtout sur cabosses, sont négligeables.

Une méthode de lutte contre les capsides et plus généralement contre le dessechement des extrémités a été mise au point

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par Monsieur Grimaldi phytopathologiste et Monsieur Lavabre entomologiste. Elle consiste en pulvérisation d'une bouillie mixte (bouillie bordelaise a I,2% et de H. C. H. a 2%) des résultats encourageants ont été enrégistrés.

Sur plantations jeunes des badigeons des troncs et des branches a base de D. D. T. émulsionné out été employés à la station du cacaoyer de Nkoémvone et se sont montrés très efficaces.

Des moyens de lutte existent donc d'une rentabilité certaine mais on rencontre des difficultés pour l'application des celles-ci en raison surtout de l'indifférence des populations locales.

Autres Parasites

D'une manière sporadique on doit signaler des attaques d'un dangereux AGROTIDE "Achea catocaloides Guen, dont les invasions de chenilles sont responsables de défoliations massives des plantations.

Les chenilles de ce papillon dévorent les feuilles des grands arbres du couvert puis se laissent descendre par un fil dans les plantations situées en dessous.

Souvent les dégats s'étendent sur plusieurs centaines de mètres de largeur et peuvent s'observer avec plus ou moins de régularité sur des bandes de plusieurs kilomètres de long.

Les dernières invasions signalées ont eu lieu en Décembre 1951 et Février 1954 (grande saison sèche).

On a intérêt a traiter les cacaoyers dès que les chenilles sont signalées sur les couverts forestiers. Des pulvérisations de D. D. T. sont efficaces contre ce parasite.

On observe encore tout au long de l'année des déprédateurs ordinairement d'importance limitée.

Signalons -

Un pentatomide piqueur des rameaux et cabosses- (Atelocera serrata. Westw)

Le psylle du cacaoyer - Mesohomotoma tessmanni Aulm)

Des chenilles défoliatrices (Prodenia litura Fab.)

Des chenilles mineuses des troncs et des branches (Eulophonotus myrmeleon Feld.)

Des chenilles de cabosses (Characoma Stictigrapta Hmps) Enfin de nombreux Cérambycides borers des troncs au l'rang desquels se placent les Tragocephala chloris Chev. et le Mallodon downesi Hope.

Terminons ce bref tour d'horizon par un tableau des espèces rencontrées de temps en temps sur les plantations.

ORTHOPTERES

Zonocerus variegatus L.
Brachytripes membranaceus Drury.

ISOPTERES

Nombreuses espèces de termites chez les sujets vieux et en mauvais état végétatif.

COLEOPTERES

Apate monachus Fab. (Bostrychide)
Apate térébrans Pall (Bostrychide)
Araecerus fasciculatus (Anthribiide)
Apodères flavoebénus (Curculionide)

LEPIDOPTERES

Anomis leona - Schaun.
Euchromia lethe F.
Marmara Sp.

HEMIPTERES

Cléterorpha Sp.
Mc ira Sp.

Cochenilles dont il est remarquable de constater le peu d'importance économique qu'élles occupent.

28 june
Cacao-205-54

5RTIC/Doc.29
Fitop/10

GROWTH OF PHYTOPHTHORA PALMIVORA OF CACAO IN LIQUID MEDIA CONTAINING CACAO SHELL FROM DIFFERENT CLONES AS A BASIS FOR ASSESSMENT OF RESISTANCE

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One of the most effective methods for the control of infectious diseases of plants is the development and propagation of resistant varieties obtained through selection and hybridization. In the case of the cacao disease caused by Phytophthora palmivora Butl. this method of control has not yet been made possible.

In 1953 (2) it was stated that the basic problem is to determine the nature of resistance to this malady and to find a method or methods that will allow the detection of disease resistance in cacao. Occasionally resistant trees of cacao have been reported to exist. However, the resistance of these has not been definitely established by studying them under various environmental conditions.

A technique commonly used in resistance testing is to spray seedlings and cuttings with a sporangial suspension of the organism. In working with a crop such as cacao it seems advisable to use cuttings as identical promising material may be propagated immediately, whereas cuttings could not be taken from the seedlings for at least a year.

Also information concerning resistance may be obtained from yield and field disease records. In certain sections of "La Lola" Cacao Experimental Farm of the Inter-American Institute of Agricultural Sciences in Costa Rica these records have been taken on individual cacao trees for the past four years.

Pethybridge and Lafferty in 1917, Moore in 1945, and Lasande in 1949, as mentioned by Boyd (1), all used the method of inoculating potato tubers with disease-producing organisms to determine the resistance of different varieties. Boyd (1) in 1952 conducted an extensive study of this method by inoculating potato tubers with Fusarium caeruleum.

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Newhall[AA] in 1947 proposed this method for the study of resistance of cacao to Phytophthora rot. He suggested the inoculation of cacao pods with a determined number of conidia of P.palmivora and the subsequent measurement of the lesions produced. He recommended that seeds and cuttings of resistant trees should then be propagated and the trees self-or cross-pollinated to fix the resistance characters.

By inoculating cacao pods of several UF clones in Costa Rica according to the method suggested by Newhall, differences in resistance were detected. Similarly, defferences were found to occur also between purple (red) and green cacao pods (2).

In an effort to find further proof of the resistance of cacao to Phytophthora, differences in the growth of this fungus in liquid media containing pod shell tissue of different UF cacao clones were measured. Shell tissue from adult but not commercially ripe pods of seven UF clones were used for the preparation of culture liquid media for the fungus. Eight different media were thus prepared. Except for the check each medium contained 50 grams of pod shell tissue from one of the clones in one liter of water plus 20 grams of dextrose. The medium used as a check contained only water and dextrose. The pH of all of these media before sterilisation was 5.5 - 0.3. Twenty-five cubic centimeters of the media were put in each Ehrlenmeyer flask. The flasks were inoculated with agar-discs of a five-day old monosporangial culture of P.palmivora # 30 and incubated at room temperature (25-27°C), Growths were measured on the basis of dry weights of the mycelium after 30 days by routine technique (Table 1).

TABLE 1

Growth expressed as dry weight of P.Palmivora # 30 after 30 days in liquid media containing cacao pod shell of seven U.F. clones.1/

Clone Number	Dry weight in mg
Check	51.4
11	46.7
12	77.5
221	79.5
667	96.4
650	98.2
613	132.5
677	168.4

1/ Pods of clonal trees 11 and 12 are green, 221 are green with purple ridges, others are purple (red).

AA Project Outlines by A.G.Newhall, I.I.A.S. Turrialba, C.R. 1947.

From Table 1 it seems apparent by the differences in growth in the media that there exist differences in the character of the pod shell tissue from the various clones. Assuming that an increase in growth of the Phytophthora implies a decrease in resistance of the pod shell tissue used in the medium, the clones in Table 1 are arranged in decreasing order of resistance. It is interesting to note that cacao pods of clonal trees 11 and 12, the most resistant in this test, were of the green type found to be the most resistant by the method of inoculating pods with a conidial suspension of Phytophthora as reported in 1953 (2). Although these results should still be considered preliminary, both methods seem to be promising in detecting differences in resistance of cacao.

An experiment is being planned to compare the methods of detecting resistance to Phytophthora rot of cacao that have been mentioned in this paper. After the resistance of certain cacao types is known in one locality, however, these types must be tested in other areas under all kinds of conditions.

SUMMARY

From differences in growth on a dry weight basis of Phytophthora palmivora of cacao in liquid media containing cacao shell pod tissue of different U.F. clones, it seems apparent that difference exist in the character of the pod shell tissue of the clones used. It is assumed that a greater amount of growth of Phytophthora implies a lower degree of resistance of the cacao shell tissue in the liquid media. This method and that of pod inoculation reported earlier (Proc. Cacao Conf. London. 1953) seems to be promising for the detection of resistance of cacao to P.palmivora.

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B I O Q U I M I C A

FORSYTH, W. G. C. The biochemistry of cacao, cacao "tannins". — 5RTIC/Doc.23 Bioq/1

GRIMALDI, J. Un procede de fermentation du cacao du Cameroun. — 5RTIC/Doc.24 Bioq/2

THE BIOCHEMISTRY OF CACAO

CACAO "TANNINS"

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INTRODUCTION

The problems of the preparation of the cacao bean for the market are fundamental and immense. Nevertheless when the literature of cacao curing is compared with that of the brewing industry, or by closer analogy, tobacco curing, the comparative paucity of information available is amazing. The process has remained a traditional art, little influenced by scientific research. This has been amply realized for some time and one result has been that our Institute was asked (1) to include in its programme "Fundamental research on the fermentation and drying of the cacao bean".

Our investigation has naturally fallen into two parallel studies:- the external microbial fermentation of the pulp (2) and the internal enzymic changes in the bean. The latter has been my province.

In agreement with my remarks above it is surely to be deplored that the author of a very recent book on Cocoa (1953) (3) should have to go back to 1897 (4) for a complete analysis of the cacao fruit as harvested.

It was immediately obvious at the start of this investigation that the first essential was to study and isolate as many as possible of the chemical components of the fresh cacao bean. These components can roughly be divided into two main fractions. Those which appear to remain essentially unchanged during the curing process; i.e. the fat, starch, and fibre, (5) and those which very obviously change; i.e. the proteins (6) and the phenolic components. We elected to study firstly the phenolic components (the cacao "tannins") and leave the proteins till later. This choice was made for two reasons:- Firstly, little was known of this "tannin" fraction, secondly, it is undoubtedly responsible for many of the changes in the taste and appearance of the bean during curing. It has now been almost completely elucidated.

The "Tannins" of Fresh Beans

In 1909 Ulteé and Van Dorssen (7) crystallised a complex of a catechin and caffeine from cacao. The catechin part was later isolated (8) and shown by Freudenberg in 1923 to be (-) epicatechin (9). Until very recently this has remained the sole crystalline phenol isolated from the cacao bean. Unfortunately it was considerably under-estimated by a method giving very poor extraction and only ca. 1.2% was found in the fresh dried bean. As shall be shown, actually 2.5 - 3.5% is present in forastero cacao.

This was naturally not realised when the methods for estimating cacao tannins were introduced. Duthie (10) for example found 3 - 4.5% of tannin precipitated by cinchonine sulphate and about the same which could be precipitated by formaldehyde - HCl after the cinchonine treatment. Duthie suggested that the secondary formaldehyde treatment estimated the catechins, but this was later denied (11). In fact the nature of the compounds estimated by any of the three methods in use - cinchonine sulphate - formaldehyde HCl - Lowenthal permanganate - was unknown. Since some 7 - 9% of extractable polyphenols are present in the fresh dry bean, it was generally believed that the bulk of the fraction was complex tannin.

The chemistry of "Tannin" is of considerable interest since it demonstrates a complete reversal of the modern trends in other branches of the chemistry of plant substances. Twenty five years ago, polysaccharides, proteins, and nucleic acids were considered to be aggregations of relatively small molecules, whereas tannins were believed to be condensed substances of high molecular weight. The former have now been shown to be long chain polymers of very high molecular weight, whereas the tannins as they occur in plants are now found to be very complex mixtures of polyphenols of relatively small molecular size (12). This has been shown to be true for tea (13), and, as shall be shown, the so-called cacao tannins are also a diverse mixture of polyphenols mainly of relatively small molecular weight.

A simple method has now been developed, based on our studies (14 - 20), for the qualitative and quantitative analyses of the phenolic fraction of cacao cotyledons. This is illustrated by its application to ten forastero cacao pods selected at random from a clonal cacao plot at San Juan Estate, Trinidad, as well as two criollo pods.

METHODS AND RESULTS

Extraction

The air dried beans are extracted with 5 parts of 0.IN HCl in a blender. The fraction of the total phenols extracted can be determined by formaldehyde - HCl precipitation. (21).

Qualitative Chromatography (22)

0.05 ml. of extract are spotted near a corner of a filter paper sheet (60 x 60 cm) and run first with water and then at right-angles in a butanol-acetic acid-water mixture. After drying the sheet is passed through a ferric chloride-potassium ferricyanide mixture which shows all the phenolic substances present as blue spots. The intensity of each spot is proportional to the amount present, and this simple assay can be used as a semiquantitative measure. By using other sprays and by actual isolation, the nature of the major components is now known. Our results with the twelve pods are shown in figure I. Four catechins and three leucocyanidins are invariably present. Two anthocyanins are always present in the purple beans although of course absent from the colourless criollo. Three minor components of unknown nature are found in five of the ten pods:- I.C.S. No. 8, 42, 49, 53, 79. That this may be a criollo characteristic is suggested by the finding that the criollos are especially rish in these compounds. Apart from this it is the similarity between the chromatograms that is most striking. The complex material near the starting point is also of a leucocyanidin nature.

Quantitative Chromatography:-

It will be observed from figure I that if the phenols could be estimated on the paper when run in water, the anthocyanins, catechins and leucoanthocyanin fractions are separated. This can readily be done by titrating horizontal strips of a one-way chromatogram with permanganate.

0.1 ml extract is streaked along the starting line of a paper strip 10 cms. wide, and allowed to chromatograph in water until the aqueous boundary has moved to 30 cms. 0.5 cm. horizontal strips are cut out and titrated with 0.01 N potassium permanganate till colour remains for 1 minute. The results are shown in figure 2, or may be converted into actual catechin and leucoanthocyanin present when control runs with pure epicatechin and cacao leucocyanidin have been made. (Table I).

TABLE I

The Polyphenols of Trinidad Forastero Cacao

(Percent Dried Cotyledon)

Clone I.C.S.	Total x	Catechins		Leucocyanidins		"Complex" +	
	T	C	as % T	L	as % T	T-(C L)	as % T
10	7.1	2.5	35	1.8	26	2.8	40
15	7.3	2.8	39	2.3	32	2.2	30
42	8.1	2.8	34	2.3	28	3.0	37
49	7.9	2.6	33	2.6	33	2.7	34
53	9.1	3.3	36	2.8	31	3.0	33
54	7.9	3.3	42	2.0	25	2.6	33
67	7.7	3.1	40	2.5	32	2.1	28
68	9.0	3.4	38	3.5	39	2.1	24
84	8.0	3.2	40	2.5	31	2.3	29
86	8.2	2.7	33	2.4	29	3.1	38
Mean	8.0	3.0	38	2.5	31	2.6	32
Range	7.1-9.1	2.5-3.4	33-42	1.8-3.5	25-39	2.1-3.1	24-40

x Determined by the method of Hallas (21) with formaldehyde - HCl, but corrected for the condensed formaldehyde. ((-) epicatechin gives a 138% yield due to addition of formaldehyde).

Includes anthocyanins, and any other simple polyphenols as well as "tannins".

+ From the table it is apparent that 60 - 75% (mean 68%) of the polyphenols are present as substances which can be individually detected and estimated.

When applied to two criollo samples (Trinidad; Tobago-Arden), much lower figures were obtained:- Total 6.0, 4.6; catechins 1.8, 1.4; leucocyanidins 1.1, 0.8; well below the forastero range. *Theobroma grandiflora* gave similar figures:- Total 4.1, catechins 1.4, leucocyanidins 1.5.

DISCUSSION

The qualitative chromatographic method is simple and quick. It should be an extremely useful tool in comparing the different species of Theobroma (cf. Th. grandiflora). When applied to the fermentation it shows the destruction of the anthocyanins during the initial period followed by the disappearance of all the other components during the drying. It is here that the quantitative method is proving most useful. The removal of the individual classes of substances can be quantitatively followed under varied fermentation treatments.

After this work was completed, Brown (23) introduced his elegant method of isolating the polyphenol storage cells of cacao cotyledons by simple sedimentation in petrol. We find simple water extracts of these cells to give identical chromatograms to the above, and to contain all the polyphenolic components of the whole bean. This confirms that our extraction procedure does not lead to artifacts, and the chromatograms are in fact "pictures of the beans".

SUMMARY

Our knowledge of this important fraction of the cacao bean is reviewed. The considerable clarification of the subject by the more recent work done here is reported. Methods have been developed for the qualitative and quantitative assessment of most of the tannin components. These are illustrated by their application to fresh and fermenting beans.

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UN PROCEDE DE FERMENTATION DU CACAO AU CAMEROUN

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La fermentation a pour but de modifier les propriétés organoleptiques des fèves - Le sèchage poursuit la modification et assure la conservation du produit.

La fermentation est un phénomène très complexe. On distingue deux fermentations: une fermentation externe et une fermentation interne.

Fermentation externe

Elle est sous la dépendance de microorganismes. (Champignons du groupe des Levures - Bactéries). La pulpe qui entoure les graines est un milieu riche en sucres réducteurs. Les sucres sont transformés en alcool et gaz carbonique: et, en présence de l'oxygene de l'air, ces alcools sont oxydés en donnant de l'acide acétique et parfois de l'acide formique.

Fermentation interne

Elle est sous la dépendance des enzymes présents dans les graines et est aidée par certains produits pénétrant à travers la "coque" (Alcool et acide acétique).

C'est essentiellement un phénomène d'oxydation qui modifie certains composants de la fève (substances tannoïdes, catéchines, cyanidol etc...), et diminue la teneur en théobromine.

Modifications apportées au cours de ces fermentations

Fermentation externe
- Destruction et séparation de la pulpe adhérente à la graine -
- Détachement des téguments originairement soudés aux cotylédons -

Fermentation interne
- Destruction d'une partie des substances amères (thébromine) et astringentes, (catéchines).
- Développement de l'arôme -
- Brunissement de l'amende -
- Modifications de certains tannins -

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Toutes ces modifications chimiques font appel a une forte quantité d'oxygène, dont l'apport est obtenu soit par brassage de la masse en fermentation dans la même caisse, soit au moment du transfert des fèves d'une caisse dans une autre. La durée de la fermentation est de 7 jours environ.

Les auteurs qui ont étudié la fermentation estiment que la zone de température la plus favorable est comprise entre 40 et 52°.

Les diastases oxydantes, entrant dans le processus de la fermentation interne ont un optimum d'action entre 41 et 45° et sont détruites à 70°.

Au dessous de 36° des moisissures (Penicillium etc...) se développent.

Nous avons donc recherché dans nos essais de fermentation
1°) à opérer dans un récipient permettant aux fèves d'être brassées en présence d'air, pour favoriser la fermentation nécessitant beaucoup d'oxygéne.

2°) à règler le nombre de brassage en fonction de la température qui doit se maintenir entre 40 et 52°.

Le récipient qui nous a paru le plus rationnel est un tonneau (fût de vin du commerce de 220 litres).

Modifications apportées à ce fût du commerce pur en faire un tonneau de fermentation

Elles consistent simplement a introduire 4 planches par des encoches pratiquées dans les deux fonds du tonneau et a ouvrir une porte au niveau de la bonde. Des trous de 8 m/m de diamètre sont percés à l'opposé de la bonde pour permettre l'écoulement des jus.

Utilisation:

Ce fût peut-être utilisé:

- tel quel, en le roulant par terre, ou mieux sur deux chevrons;
- sur un axe en bois, en prenant soin de consolider les deux fonds;
- en employant tout système permettant une rotation autour de l'axe de symétrie du fût.

Contenance

La contenance d'un fût est environ de 220 litres. D'après

nos calculs, les fèves fraîches pèsent environ 930 kilogrammes au mètre cube; au bout du 4ème jour, les fèves ont gonflé et ne pèsent plus que 780 kgs au mètre cube, elles ont atteint alors leur maximum de volume. Compte tenu de ces données et de ce qu'il faut laisser un volume libre de 40litres pour permettre un brassage efficace, la contenance maximum en fèves fraîches du fût sera de: 180 x 0,78 = 140 kilogrammes soit en tenant compte des pertes en liquide, 150 kgs. (Ce qui représente 1.300 a 1.500 cabosses), et la contenance minimum de 60 kgs. (c'est à dire 500 a 600 cabosses).

Brassage

Les meilleurs résultats nous ont été donnés par:

- un brassage, 48 heures après la mise dans le tonneau -
- un brassage 3 fois par jour dès que le fût chauffe, c'est a dire en général au bout de 4 jours; la fermentation dure 7 - 8 - 9 ou 10 jours selon:

- La température extérieure -
- La contenance en eau des fèves-

Tout le cacao que nous avons obtenu par cette méthode a été classé supérieur par les Services du Conditionnement. L'adjonction de feuilles de bananier dans la masse de fèves, facilite, par les levures qu'elles apportent, le départ de la fermentation et en réduit la durée.

Avantages du procédé

- Construction rapide et facile;
- prix de revient faible;
- facilité d'emploi;
- brassage automatique;
- ne nécessite pas de transvasement;
- permet une surveillance constante de la fermentation;
- ne nécessite qu'un effort très faible pour rouler ou tourner le tonneau.

RÉSUMÉ

L'emploi d'un tonneau de fermentation de construction simple, permet avec un travail plus facile, d'obtenir du cacao bien fermenté, et d'une façon très homogène.

- FICHE DE FERMENTATION N° 2 -

FUT N° 4

Début de fermentation: 21-9- 16 H.

Tourné le: 23-9- 16 H.

Nombre de brassages: 3 (7h-12h-19H.) dès que le fût chauffe

Fin de fermentation: 29 Septembre 8 H.

Nombre de cabosses:	1.429
Poids de cabosses :	485, 5 kgs
Poids de fèves fraîches:	127 kgs
Poids moyen d'une cabosse:	340,4 gr.
Poids moyen de fèves :	88,87 gr.
Rapport $\frac{\text{Poids de fèves fraîches}}{\text{Poids de cabosses}}$:	26,1 %
Poids de fermentées:	108,4 kgs
Rapport $\frac{\text{Poids de fèves fermentées}}{\text{Poids de fèves fraîches}}$:	85,35%
Poids de fèves sèches:	55 kgs
Rapport $\frac{\text{Poids de fèves sèches}}{\text{Poids de fèves fraîches}}$	43,3 %
Rapport $\frac{\text{Poids de fèves sèches}}{\text{Poids de fèves fermentées}}$	50,7 %
Rapport $\frac{\text{Poids de fèves sèches}}{\text{Poids de cabosses}}$	11,3 %
Poids de fèves sèches par cabosse:	38,4 gr
Nombre de cabosses nécessaires à l'obtention d'un kilogramme de cacao sec:	26

- FICHE DE FERMENTATION N° II -

FUT N° IV ET V

Début de fermentation	3 Octobre à 12 H.
Tourné le:	5 Octobre 12 H.
Nombre de brassages:	3-(7h-12h-19 H.) dès que le fût chauffe.
Fin de fermentation:	13 Octobre a 12 H.
Nombre de cabosses:	2.781
Poids de cabosses:	927,4 kg
Poids de fèves fraîches:	271 kg
Poids moyen d'une cabosse:	333,4 gr
Poids moyen de fèves d'un cabosse:	97,66 gr
Rapport $\frac{\text{Poids de fèves fraîches}}{\text{Poids de cabosses}}$:	29,28 %
Poids de fèves fermentées :	210,3 kg
Rapport $\frac{\text{Poids de fèves fermentées}}{\text{Poids de fèves fraîches}}$	77,6 %
Poids de fèves sèches	105,2 kg
Rapport $\frac{\text{Poids de fèves sèches}}{\text{Poids de fèves fraîches}}$	39 %
Rapport $\frac{\text{Poids de fèves sèches}}{\text{Poids de fèves fermentées}}$	50 %
Rapport $\frac{\text{Poids de fèves sèches}}{\text{Poids de cabosses}}$	11,34 %
Poids de fèves par cabosse:	37,8 gr
Nombre de cabosses nécessaires à l'obtention d'un kilogramme de cacao sec.	26-27

22 June 1954
CACAO-191-54

S E L E C C I O N

IMLE, E. P., ERICKSON, A. L., and L. P. OECHSLI. Performance of clonal cuttings and clonal seedlings of cacao inter -- planted with rubber.

5RTIC/Doc.25
Sel/1

PERFORMANCE OF CLONAL CUTTINGS AND CLONAL SEEDLINGS OF CACAO INTERPLANTED WITH RUBBER

Ernest P. Imle, A. L. Erickson, and L. Paul Oechsli 1/

INTRODUCTION

The United States Department of Agriculture Regional Rubber Experiment Station with headquarters at Turrialba, Costa Rica has been interested in testing complementary crops to be grown with rubber. Rubber and cacao are crops for which the world price has fluctuated widely over the years. In general both are adapted to similar climate and soil conditions. *Hevea brasiliensis*, the rubber tree of commerce, is a high-growing crop and cacao a lower-growing crop. It is natural that interest has developed in growing the two crops in permanent mixture.

Early attempts to grow these crops together were not entirely satisfactory. A full stand of cacao usually was planted and the rubber trees then planted at some distance like 40 feet by 40 feet over the area. This resulted in the tapping panels of the scattered rubber trees being densely surrounded and shaded by the cacao leaves and branches. This condition favored the destructive black stripe disease of the tapping panel caused by *Phytophthora palmivora* and moldy rot caused by species of *Ceratostomella*. Likewise the costs of tapping rubber trees planted at this distance and often nearly inaccessible to the tapper because of the cacao branches, were too high, even in the absence of serious panel diseases, to make it a profitable business except in times of good rubber prices.

Theoretically the two crops should be complementary on the same farm. During peak labor demands for cacao the rubber need not be tapped. When cacao demands less labor the surplus could be devoted to daily rubber production. To study some of these points a small pilot test was planted at the United States Department of Agriculture Regional Rubber Station at Turrialba. The three-component or double-budded were transplanted to the field in June, 1950 and the cacao seedlings and rooted cuttings were transplanted in May, 1950. Through the courtesy of Mr. Walter Hamer, Manager of the Compañía Bananera de Costa Rica, clonal seeds 2/ and rooted clonal cuttings

1/ Director, USDA Regional Experiment Station, Turrialba; Horticulturist, Inter-American Cacao Center, IAIAS, Turrialba; and Director of Research, American Cocoa Research Institute, respectively.
2/ Open pollinated but from trees grown in large clonal comparison blocks.

were obtained free of charge from the Company's propagation center at Zent, Costa Rica.

These United Fruit Co. clones were selected for vigor and production in the heavily Phytophthora-infested Atlantic Zone of Costa Rica and it seemed likely that the selection process might well have yielded some clones with at least some degree of field resistance to Phytophthora palmivora or to other pathogens.

By 1950 the Regional Rubber Station had selected from among certain hybrid rubber clones from Brazil some which appeared to have a satisfactory degree of resistance to Phytophthora leaf fall. The time thus seemed appropriate for a pilot test of rubber and cacao in permanent mixture using for each crop selected plant material on which Phytophthora might not cause severe damage. In another nearby rubber test we have noted repeated and severe defoliation of rubber trees caused by Phytophthora palmivora but no injury to producing-cacao trees growing under them. We know of no evidence which indicates that Phytophthora damage will be worse on either of these two crops grown in a properly planted mixture than when they are grown separately.

Land and plant material limitations did not permit trial of more than one spacing system in this small pilot planting. A spacing was chosen which, it was hoped, would permit eventual permanent production of both crops from the same piece of land without either one damaging or reducing the other.

EXPERIMENTAL DESIGN AND PLANTING

The rubber trees were planted in double row hedges at six by ten feet. The cacao was planted at ten by ten feet in the 90 ft. wide strips between the double rubber rows, leaving 15 feet between the rubber and the first cacao row. This resulted in 145 rubber trees per acre and 304 cacao trees per acre or about 70 per cent of a normal full stand of each crop. In this system each rubber tree has one side open for non-competitive development and the 15 feet wide alley ways between the rubber and the cacao guarantee free access to the rubber trees for tapping. They also can serve as roadways for spraying and servicing the cacao planting.

It is believed that this spacing will permit better aeration of the rubber tapping panels than would exist in a normally planted pure stand of rubber and that diseases of the tapping panel may be easily controlled.

The cacao planting was designed to give information on the performance of cuttings and seedlings of some of the United Fruit Company clones from Costa Rica. The plants were set out in three blocks of 147 trees each, with 21 rows of seven trees each to the block. The first block contains trees grown from seed of six United Fruit Company clones replicated three times with a buffer row at each end and a control row in the middle of the block. The second and third blocks contain trees grown from cuttings of four United Fruit Company clones replicated four times in each block and with control rows between the replicates and buffer rows at both ends of the blocks. The buffer rows and control rows are planted with unselected seedlings from the Atlantic coastal cacao area.

Unfortunately some mixtures occurred, probably at the source of the rooted cuttings, and all the clonal rows are not pure. Plants have been identified however wherever possible. In the analysis below only data from definitely-identified plants have been included.

MAINTENANCE OF EXPERIMENT

Some supplying of trees was continued over the first two years whenever plants died. Survival records of the plant material in this test may be of interest and are given below.

Plant Material

	Clone 613	Clone 650	Clone 667	Clone 668	Clonal seedlings	Ordinary seedlings
N°. Planted	56	56	56	56	126	91
N°. supplied	0	9	19	32	18	28
Survival	100%	84%	67%	43%	86%	70%

Formation pruning was initiated in the third year but probably should have been started earlier. Initially Leucaena glauca was planted for temporary or provisional shade over the cacao but it failed to develop adequately and was later replaced by a single row of Albizzia sumatrana down the center of each cacao block, at intervals of 20 feet. During the fourth year the Albizzia shade was removed from one half of each block leaving only the hedge rows of rubber which provided a small amount of side shade.

A cover crop of Indigofera endecaphylla was maintained in the area during the first 2 years but this cover disappeared when the plants began to shade the ground. Fertilizer has been applied to the cacao as indicated below:

Date	Formula	Amount applied per plant
Oct. 1950	10-10-10	75 gms.
Jan. 1951	10-10-10	100 "
Apr. 1951	0-10-10	100 "
Aug. 1951	Nitrofoska	225 "
Dec. 1951	Nitrofoska	225 "
May 1952	Nitrofoska	225 "
Dec. 1952	12-8-0	300 "
June 1953	EMJEO (28% Mgo)	500 "
	Borax	30 "
	Chilean Nitrate	200 "
Mar. 1954	Urea	75 "
	0-24-8	100 "

Two sprays applications containing minor elements were applied, one in the third year and one in the fourth year.

Several applications of fungicidal sprays have been applied but not according to any definite schedule. The materials used were, Tennessee 34 Copper, Fermate, and Dithane.

EXPERIMENTAL RESULTS AND DISCUSSION

During the fourth year from planting in the field, the cacao pods harvested per tree were counted at monthly intervals. In the seedling section and in one of the cutting sections, an individual row of seven trees was selected to represent each clone. Each pod from these selected rows was weighed intact, then cut open, and the wet weight of the beans recorded. From these samples the average wet weight of beans per pod was calculated for each clone. This factor was multiplied by the number of pods per tree to calculate the production in bean weight per tree. The data taken at monthly intervals from June 1953 to June 1954 are summarized in the following tables.

TABLE No. 1

Average Production per Tree for Four-Year-Old Trees Grown from Seed. June 1953 to June 1954. U. S. Department of Agriculture Rubber Station, Turrialba, C. R.

Trees from seed	Number of pods/tree	Ave.wet wt. of beans per pod (gms.)	Ave.wet wt. of beans per tree (gms.)
Unselected	16.1	100	1610
U.F. 650	13.5	114	1539
U.F. 676	54.7	75	4103 1/
U.F. 667	23.4	117	2738
U.F. 613	22.4	102	2285
U.F. 668	16.0	93	1488
U.F. 654	29.9	93	2781
Average 2/	26.6	98	2607

1/ Significant difference between clonal seedlings 676 and all other seedlings (F=4.846).

2/ Average of clonal seedlings.

TABLE No. 2

Average Production per Tree for Four-Year-Old Trees Grown from Rooted Cuttings and Unselected Seed. June 1953 to June 1954. U. S. Department of Agriculture, Rubber Station, Turrialba, C.R.

Trees from	Number of pods/tree	Ave.wet wt. of beans per pod (gms.)	Ave.wet wt. of beans per tree (gms.)
Unselected seed	14.8	-	1484 1/
Rooted cuttings of:			
U.F. 668	12.0	167	2021
U.F. 613	13.2	134	1769
U.F. 650	15.9	147	2337
U.F. 667	15.9	141	2242
Average 2/	14.3	147	2102

1/ Significant difference between unselected seedling and trees grown from rooted cuttings (F=4.343).

2/ Average of rooted cuttings only.

The yields of all of the varieties were excellent for a four-year-old planting. In the seedling section, trees grown from seed of U.F.676 had a significantly higher production at the five per cent level than all the other seedlings. In the rooted cutting block, all of the rooted cuttings yielded significantly more than the unselected seedlings at the five per cent level. The experimental design does not permit a statistical comparison between the seedling block and the rooted cutting blocks.

The average wet weight of beans per tree produced by seedling trees was about 500 grams greater than that for the trees from cuttings (seedlings, 2607 gms per tree and cuttings 2102 gms. per tree). This difference is due largely to the significantly high production of seedlings of U.F.676. If U.F.676 seedlings are excluded the average wet weight of beans per tree for seedlings is 2166 gms., only 64 grams greater than for the cuttings.

Comparing the rooted cuttings with their corresponding clonal seedlings (U.F.613, 650, 667, 668), the cuttings averaged 2.1 kilos per tree and the seedlings averaged 2.0 kilos per tree. There did not appear to be any correlation between the yields of the cuttings and their corresponding clonal seedlings (see Table No. 3).

TABLE No. 3

Comparison of Yields of Rooted Cuttings of Clones and their Corresponding Clonal Seedlings. U. S. Department of Agriculture, Rubber Station, Turrialba, Costa Rica.

Clone	Cuttings Kilos wet beans per tree	Seedlings Kilos wet beans per tree
U.F. 650	2.3	1.5
U.F. 667	2.2	2.7
U.F. 668	2.0	1.5
U.F. 613	1.8	2.3
Average	2.1	2.0

In table N°.4 the cuttings and seedlings are arranged in descending order of productivity showing the calculated dry weight per tree and the theoretical production in pounds of dry beans per acre.

TABLE N°. 4

Production in Pounds per Tree and Pounds per Acre. June 1953 to June 1954. U.S. Department of Agriculture, Rubber Station, Turrialba, C.R.

		Calculated dry wt. of 1/ beans per tree (lbs).	Calculated 2/ lbs/ acre
Seed	676	3.4	1.479
"	654	2.3	1.000
"	667	2.3	1.000
Cuttings	650	2.0	870
Seed	613	1.9	827
Cuttings	667	1.9	827
"	668	1.7	740
"	613	1.5	653
Unselected seed		1.3	566
Seed	650	1.3	566
"	668	1.2	522

1/ Dry weight was determined by taking 38 per cent of the wet weight.

2/ Based on same spacing as used in this planting with 435 trees per acre.

To obtain information about relative bean size, a sample of 250 grms. of wet beans was taken from each tree at each harvest in the selected-sample-rows and the number of beans were counted. If the beans were small, it required a larger number to make 250 grms. than if the beans were large. The 250 grms of fresh wet beans is approximately equivalent to 100 grms of dry beans.

With the exception of rooted cuttings of U.F.613, all of the rooted cuttings had decidedly larger beans than the seedlings. (see table 5) the average bean size index for trees grown from seed was 70 beans per 100 grms dry am for trees grown rooted cuttings it was 43 beans per

100 grms dry. The importance of this difference in bean size can only be determined by the value that manufacturers may place on large beans as compared with small beans.

TABLE N°. 5

Variation in Size of Bean

Variety	Ave.number of beans per 100grams dry.
Seed of U.F. 676	82
Seed of unselected cacao	78
Seed of U.F. 613	75
Seed of U.F. 668	71
Seed of U.F. 654	67
Seed of U.F. 650	67
Rooted cuttings of 613	60
Seed of U.F 667	57
Rooted cutting of 667	39
Rooted cutting of 668	39
Rooted cutting of 650	38

There was a considerable difference between seedlings and rooted cutings with reference to the weight of wet beans per pod (see table 6). On the average the pods from the rooted cuttings produced approximately 50 per cent more (147 grams per pod) than the pods from seedlings (98 grams per pod). Since harvesting and breaking costs Account for 35 per cent to 45 per cent of the labor costs of producing cacao, this higher production per pod could have a significant bearing on production costs.

Because of the great variation in the average weight of beans per pod for different clones comparative production date must be based on weight of beans and not on number of pods. However, representative sample to determine the weight of beans per pod for each clone is probably adequate. This factor can then be multiplied by the number of pods for each clone to get the total production by weight.

The ratio of wet weight of beans to total weight of pod was calculated on a percentage basis (see table 6). For seedlings this percentage was 19 per cent and for cuttings it was 21.3 per cent. The variation, however, was not great.

TABLE N°. 6

Comparisons of Average Wet Weight of Beans per Pood Average Weight of Pods, and Percentage of Beans to Pod by Weight for Rooted Cuttings and Seedlings. U.S.D.A. Rubber Station.

Trees grown from	Ave.weight of wet beans per pod gms.	Ave.weigh of pods	% of wet beans to pod weight
Cuttings of			
U.F. 668	167	746	22.4
U.F. 650	147	731	20.1
U.F. 667	141	622	22.7
U.F. 613	134	658	20.4
Seed of			
U.F. 667	117	544	21.5
U.F. 650	114	550	20.7
U.F. 613	102	632	16.1
Unselected seed	100	485	20.6
Seed of.			
U.F. 668	93	434	21.4
U,F. 654	93	498	12.7
U.F. 676	95	410	18.3
Average cuttings	147	689	21.3
Average clone seedling	98	516	19.0
Average unselected "	100	485	20.6

Although this planting was designed primarily to test a system of growing cacao and rubber together it has provided valuable data on the performance of clonal seed of cacao and rooted cuttings of clones. In spite of the fact that the planting is small and only four years old several conclusions and suggestions can be set forth which should be of value to others working on cacao.

CONCLUSIONS

As might be expected rooted cuttings of cacao clones significantly out yielded trees grown from unselected seed. Also, trees grown from seeds of certain clones produced exceptionally well. There was no correlation, however, between the yields of rooted-cuttings of given clones and seedlings of the same clones.

From the results obtained it appears that it would be of value to include the seed of clones as well as rooted cuttings in future comparison tests of selected cacao. Also, more attention should probably be given to testing and comparing clonal seed using controlled pollination to obtain selfed seed and selected crosses.

Due to the great variation in production per pod it is essential that yield comparisons be based on weight of beans produced and not number of pods when comparing different clones or varieties.

It is too early to recommend mixed culture of rubber and cacao for large commercial plantings. We now know that some of the rubber clones in this test are not adequately resistant to Phytophthora and these clones certainly will be attacked to some extent once they start producing seed pods. At that time the Phytophthora inoculum will be increased in the planting. Yield and disease records over the next four or five years will be necessary before any recommendations can be made. Larger tests of this kind in several areas are needed. To date both crops are growing well and cacao yields have been very satifactory for age of the trees.

If this combination of crops succeeds it offers a means of diversification for the lowland farmer, a chance for increased production per unit of land area, and, a greater efficiency in the use of available labor.

Double hedge rows of rubber at six by ten feet probably represent the maximum density at which planting should be done but even here it appears that 100 trees per acre will be tappable for a number of years, before thinning is necessary.

The 15 feet wide alleyways between the rubber and cacao were almost closed over at the end of the fourth year indicating that root competition between the two crops probably will occur from the fourth year on.

SUMMARY

1. Seedlings of six United Fruit Company clones were compared among themselves, and seedlings of U.F. 676 produced fifty percent more in weight of beans per tree than the next highest seedlings.

2. Cuttings of four U.F. Co. clones were compared with each other and with unselected seedlings. Although there were no large differences in production among the cuttings they produced significantly higher yields than the unselected seedlings.

3. The design of the experiment does not permit a statistical comparison between seedlings and cuttings. The average production for the seedling trees (including six clones) is higher than that for the trees grown from cuttings (including four clones) in the fourth year from transplanting to the field. The difference is due mainly to clone 676 which is found only in the seedling section but not in the cutting section. In comparing only those four clones found in both the cutting and seedling sections, there was very little difference in production between the seedlings and cuttings with the latter producing slightly more.

4. The average wet weight of beans per pod for the trees grown from cuttings was fifty percent greater than that for the seedlings.

5. The average size of the beans from plants grown from cuttings was considerably larger than those of plants grown from seed.

6. The four U.F. clones used in this test showed a markedly higher degree of resistance to a foliage disease than did the plants produced by ordinary unselected seed from the Atlantic Zone.

G E N E R A L

ERICKSON, A. L. Facilities and projects of various agricultural institutions working on cacao in the Western Hemisphere.	5RTIC/Doc.31 Gen/1
BURGOS, J. A. Algunos resultados del trabajo experimental sobre cacao en la Estación Experimental Agrícola en Tingo María, Perú	5RTIC/Doc.27 Gen/3
_____. Comentarios y recomendaciones sobre el cultivo del cacao en las provincias de Jaen y Bagua, Perú.	5RTIC/Doc.28 Gen/4

FACILITIES AND PROJECTS OF VARIOUS AGRICULTURAL INSTITUTIONS WORKING ON CACAO IN THE WESTERN HEMISPHERE

Compiled by A. L. Erickson *
Inter-American Cacao Center

About twenty-five questionnaires were sent to all the known agricultural research stations in the western hemisphere. Some stations do not have a cacao research program and consequently were not able to complete the questionnaire. Other stations did not reply at all and therefore, are not included in the compilation. Hence the material found on the following pages does not represent the total cacao program.

From the little information available about projects on the questionnaire it was difficult sometimes to classify them in question 8a. into the exact project heading. Allowing for a few minor errors the table gives some idea of what kind of work the various stations are doing.

The following three ministries do not have a cacao program under way and were not able to complete the questionnaire.

1. Department of Agriculture, Jamaica, B.W.I.

2. Ministerio de Agricultura, Ganadería y Colonización, La Paz, Bolivia, S.A.

3. Ministerio de Agricultura, Comercio e Industria, Panamá, República de Panamá

1. Name of research organization
2. Address and
3. Name of Director

I.

1. Trust Territory of the Pacific Islands, Cacao Nursery and Propagation Center.
2. Koror, Western Caroline Islands, Trust Territory of the Pacific Islands
3. Stanley L. Darby, Project Manager

* Horticulturist, Inter-American Cacao Center, Inter-American Institute of Agricultural Sciences, Turrialba, C.R.

1. Name of research organization
2. Address
3. Name of Director

II.

1. Cocoa Industry Improvement Scheme, Mt. Horne Cocoa Station, St. Andrew's, Grenada, B.W.I.

   a. Main Station - Mt. Horne
   b. Substations - Ashenden
                - Naran

2. Mt. Horne Cocoa Station, St. Andrew's, Grenada

3. D. A. Perryman

III.

1. The Imperial College of Tropical Agriculture

2. St. Augustine, Trinidad, B.W.I.

3. G. A. C. Herklots

IV.

1. Empresa Para Renovación de Cacao, C.A.

2. Guayaquil, Ecuador, Apartado de Correo 4664

   Propagating Center No. 1 - Babahoyo - Los Rios
   " " " 2 - Vinces - Vinces
   " " " 3 - Naranjal - Guayas
   " " " 4 - Rocafuerte - "
   " " " 5 - Machala - El Oro

3. Jorge Wagner G., President

V.

1. Estación Experimental Agrícola Tropical del Ecuador
2. c/o Consultado Americano, Gauayaquil, Ecuador

3. F. L. Steve O'Rourke

1. Name of research organization
2. Address
3. Name of Director

VI.

1. Campaña Nacional de Cacao

2. Headquarters, Estación Agrícola, Palmira, Valle, Colombia

3. Celso García B., Chief Coordinator Cacao Campaign
Gerhard Naundorf, Chief Research Section

VII.

1. Estación Experimental Agrícola en Tingo María

2. c/o Ministerio de Agricultura, Lima, Peru

3.

VIII.

1. Landbouwproefstation (Agricultural Experimental Station)
2. P.O. Box 160, Paramaribo, Surinam, S.A.

3. F. W. Ostendorf

IX.

1. Estación Experimental de Cultivos Tropicales

2. Apartado No. 96, Tapachula, Chis, Mexico

3. Ing. J. Guadalupe Escamilla

X.

1. Inter-American Institute of Agricultural Sciences

2. Turrialba, Costa Rica

3. R. H. Allee

4a. List of Personnel - Name and position

I. Stanley L. Darby, Project Manager

II. D. A. Perryman, Agricultural Officer

R. C. M. Jack, Agricultural Assistant

G. La Grenade, Junior Agricultural Assistant

G. L. Ogilvie, Senior Agricultural Assistant

N. D. Nedd)
B. A. Pitt)
C. Augustine) Junior Agricultural Instructors
J. Ferreira)

R. Mark)
D. Mahon) Foremen all stations
J. Marshall)

III. G. A. C. Herklots, Director

F. W. Cope, Senior Plant Breeder

B. G. D. Bartley, Junior Plant Breeder

D. B. Murray, Senior Plant Physiologist

R. Nichols, Junior Plant Physiologist

G. Havord, Senior Soil Chemist

C. K. Maliphant, Junior Soil Chemist

K. W. de Witt, Biochemist

P. C. Holliday, Plant Pathologist

P. G. Fennah, Entomologist

R. Ross, Manager, River Estate

V. E. White, Assistant Manager, River Estate

IV. Jorge Wagner G., President

Carlos Zavala Gangotena, Manager

Directors: José A. de Rubira Ramos
Ramón L. Espinel M.

4a. List of Personnel - Name and position

IV. Directors: Lisímaco Guzmán A.

José Felipe Mata V.

Abel Gilbert V., Assistant to the Manager

Gustavo Wray A., Meteorologist

Homero V. Castro Z., Inspector New Plantations

Jorge Saldaña A., in charge Center No. 1, Babahoyo

Eduardo Vivero, in charge Center No. 2, Vinces

Eduardo Arriaga M., in charge Center No. 3, Naranjal

José Ruíz F., in charge Center No. 4, Rocafuerte

Oswaldo Guerra P., in charge Center No. 5, Machala

V. F. L. Steve O'Rourke, Director and Horticulturist

Jaime Alzamora, Associate Director

Russell Desrosiers, Plant Pathologist

César Quiroga R., Technician in Horticulture

Carlos Bolaños S., Technician in Plant Pathology

Rómulo Villalba P., Technician in Agronomy

VI. Celso García B., Chief Coordinator Cacao Campaign

Gerhard Naundorf, Chief Research Section

Reinaldo Miller M., Assistant Research Section

Carlos Becerra Z., " " "

Rafael Cuadros C., Chief Extension Service - Palmira

Mario Sanclemente P.," " " - Tuluá

Oscar Arana M., " " " - Pto.Tejada

Jaime Medina P., " " " - Neiva

Gustavo Arroyave " " " - Garzón

4a. List of Personnel - Name and position

VII. J. Burgos, Chief Department of Horticulture

VIII. F. W. Ostendorf, Director

IX.

X. Damon Boynton, Head Plant Industry Department and Director of Research and Education

Paulo de T. Alvim, Plant Physiologist and Coordinator of Research

Arnold L. Erickson, Associate Horticulturist

Francisco García, Assistant Horticulturist

Rodrigo G. Orellana, Plant Pathologist

Luis R. Siller, Assistant Plant Pathologist

Luis A. Paredes, Farm Administrator, La Lola Farm

4. Number of Personnel Employed by the Program

a. Technicians, including technical assistants

I. Trust Territory of the Pacific Islands None listed

II. St. Andrew's Grenada - 11

III. St. Augustine, Trinidad - 12

IV. Empresa Para Renovación de Cacao, Ecuador - 12

V. Estación Experimental Agrícola, Ecuador - 6

VI. Campaña Nac. de Cacao, Colombia - 7

VII. Estación Exp. Agrícola en Tingo María, Perú - 1

VIII. Agric. Exp. Sta. Paramaribo, Surinam - 50 includes 14 with university or agricultural training.

IX. Estación Exp. de Cultivos Tropicales, Mexico

X. Instituto, Turrialba - 7

4. Number of Personnel Employed by the Program

b. Non-technical laborers

I. Trust Territory of the Pacific Islands - 85

II. St. Andrew's Grenada - 70-120

III. - - -

IV. Empresa para Renovación de Cacao, Ecuador - 63

V. Estación Experimental Agrícola, Ecuador - 60-80

VI. Campaña Nac. de Cacao, Colombia - 12

VII. Estación Exp. Agrícola en Tingo María, Perú - 4

VIII. Agric. Exp. Sta. Paramaribo, Surinam - 75

IX. - - -

X. Instituto, Turrialba - 30-35.

5. Climatological Data

	Elevation (meters)	Average Temperature Max.(c)	Min.(c)	Average monthly rainfall (mm.)	Dry Season
I	60	30.5	24	312	Jan-June (Slight)
II Mt. Horne	180	-	-	198	Feb-May
Ashenden	300	-	-	225	Feb-May
Moran	60	-	-	235	Feb-May
III	15	30	21.4	143	Jan-May (with some rain)
IV				J F M A M	
Babahoyo	5	30.4	20.2	388 282 435 534 104	June-Dec.
Vinces	41	30.5	20.7	459 292 265 345 275	
Naranjal	41	30.5	20.7	341 536 445 692 298	
Rocafuerte	72	30.4	20.8	193 268 363 314 120	
Machala	4	28.8	21.0	113 148 166 58 55	
V	75	32.4	18.4	190	June-Dec. or Jan.
VI	1000	30	18	989.5	Jan-Mar. and July-Sept.
VII	670	30.1	18.8	284	July-Aug.
VIII	Sea level	30.9	22.7	191	Aug-Nov. 15 (Also Feb. 1 - Mar. 15)
IX	450	32	18	450	Jan-May
X Turrialba	600	27	18	225	Jan-Mar.
La Lola	39	30	21	280	

6. Finances

	Total Budget U.S. Dollars	Administration	Research	Extension
I	34,500	-	-	-
II	5,000 (1)	-	-	-
III	-	-	-	-
IV	56,300 (2)	Total budget	None	None
V	32,000	16,000	16,000	-
VI	268,000 (3)	21,600	32,400	204,000
VII	-	-	3,200 (4)	Very little
VIII	142,100 (5) Res. Station proper.	-	-	-
[illegible]	38,000 Cacao prop. Sta.	-	-	-
IX	150,000	15,000	135,000	-
X	82,000	5,000	77,000 Incl. mainten. of La Lola	-

1) $1.7 BWI - $1.00 U.S.
2) 205.1 sucres - $1.00 U.S.
3) 2.5 to $1.00 U.S.
4) 18 Sol - $1.00 U.S.
5) SF 1.9 - $1.00 U.S.

7. Physical organization of the station

	a) Total area (acres)	b) Area planted to cacao (acres)	c) Area in cacao expts.. (acres)	d) Green-house area	e) Nursery area (acres)	f) Capacity for prop. by rooted cutt.
I	300	100	100	None	1	None at present
II Mt. Horne	22.5	9	6	(1)	3	100,000 per year
Ashenden	48	8	5	(2)	3	55,000 " "
Moran	18	5.5	3.5	(3)	2	45,000 " "
III	400	150	120	1500 sq.ft.	2	10,000 " "
IV	10 ea.sta.	7.4 ea.sta.	0	0	2.5	30,000 " mos ea.sta.
V	2925	494	25	0.25 A	0.25 A	300 clones of 25 stock plants each. (10 A)
VI Est. Agr.	1.6	8	-	-	12.8	450,000 annual
Pto. Tejada	-	32	-	-	16	
Cent.Prop.Tulua	-	6.4	-	-	8	(for 5)
VII	741	2.5	1.7	-	0.4	2 units 6 m. x 1.8 m. each
VIII	-	-	-	-	-	200,000 per year
IX	499	49	10	0.05 A	25	50,000 monthly
X Turrialba	2500	6	5	(4)	2	10,000 per year
La Lola	230	222	-	None	1.63	2,300 per month

(1) a. 2,000 sq.ft. glass galv.wired shed, b. 60,000 sq.ft. bamboo lath wired shed; (2) a. 1,700 sq.ft., b. 14,000 sq.ft.; (3) a. 2,000 sq.ft., b. 2,500 sq.ft.; (4) 600 sq.ft.and lath house.

7g. What phases of laboratory research can be conducted with the facilities available at your station.

I. Soil testing

II. None

III. Physiology, genetics, pathology, entomology, biochemistry, soil physics, soil chemistry.

IV. None

V. Plant pathology, entomology, soils

VI. All phases

VII. Leaf and soil analyses

VIII. Soils, diseases and pests

IX. Work being planned

X. Physiology, pathology, chemistry

7h. Extent to which research is carried on with private farmers or other agencies.

I. Extension service offered to farmers, research on entomological problems handled by the staff entomologist of the Trust Territory.

II. Five of fourteen trials are conducted on private farms, also a few observational plots on private farms.

III. Considerable

IV. None

V. Cacao clonal test blocks on 10 farms

VI. Control of diseases and pests, rehabilitation of plantations.

VII. Some cooperation in interchange of planting material. Contacts with cacao technicians abroad.

VIII. Clone testing, preparation, small holdings problems

IX. In constant contact with farms. Propagating material from the neighbouring farms.

X. A program is being developed with the extension service to distribute clonal seedlings and cuttings to farmers. It is hoped to establish these plantings as clonal comparisons.

8a. Research Problems

	I	II	III	IV	V	VI	VII	VIII	IX	X
Vegetative propagation	(1)		x	(2)	x	x	x	x		
Budding and grafting			x		x		x			
Types of prop.			x				x			x
Disease control					x	x	x			x
Monilia					x					
Phytophthora			x							x
Witches' broom			x		x					
Insect control										
Clonal and yield testing		x	x		x		x	x	x	x
Selection			x		x	x				x
Progeny testing			x						x	x
Physiology			x			x				x
Cherelle wilt			x							x
Nutrition			x			x				x
Tissue testing			x							x
Mulching		x	x				x			
Fertilizers		x	x		x		x			x
Soils			x							x
Cultural practices		x	x			x	x			x
Spacing			x		x		x			
Pruning			x		x					x
Shading			x							x
Shade trees			x				x			
Breeding			x		x					
Variety collect.			x		x					x
Incompatibility			x			x				
Nursery practic.			x							x
Growth and flowering			x		x					x
Biochemistry			x							
Quality studies			x		x					
Processing fermentation			x				x		x	

1) Planting 300 acres of Criollo cacao to study possibilities and limitations of cacao in area and to help small farmers establish small scale plantings.
2) Commercial clonal production.

8b. Type of research for which station is best equipped in terms of personnel and facilities.

I. Planting

II. Applied research, long-term field experiments.

III. Entomology, biochemistry, physiology, genetics pathology, soil physics, soil chemistry.

IV. None

V. Clone testing, hybridization, disease control.

VI. Physiology, genetics (selection), vegetative propagation, disease and pest control methods, plant pathology, entomology, soils.

VII. Fundamental research.

VIII. Soils, general agricultural problems.

IX. -

X. Physiology, pathology disease control (spray equipment), propagation.

8c. Major cacao problems on which more work should be done.

I. Soils, plant pathology, insect and pest control.

II. Shade, liming, cacao beetle, quality of clonal material.

III. To increase yields by all possible methods, genetics, physiology, pathology and agronomy. Quality studies, pest and diseases by direct control and breeding for resistance, maintenance of soil fertility, and agronomy--spacing, shading, pruning, etc.

IV. Disease control.

V. Clonal testing and disease control.

VI. Fruit set, rehabilitation, disease control, control of Moniliasis.

VII. Witches' broom control, extension.

VIII. Breeding, planting density, Stelrastoma control.

IX. Extension on modern methods of cultivation, preparation of bean for sale.

X. Processing, economic studies, shading, drainage, disease resistance.

9a. Field in which organization prepared to train technicians and/or students.

I. None at present. Basic cultivation methods to be handled as extension service.

II. None

III. Any field depending on qualifications of students.

IV. A course for graduate students in propagation.

V. Horticulture and pathology.

VI. Investigation and extension.

VII. Research and cultural practices.

VIII. None

IX. Organizing a cacao training program.

X. Pathology, physiology, agronomic practices, horticulture.

9b. Are funds available for exchange of personnel?

I. No

II. No

III. No

IV. Yes

V. No (maybe later)

VI. Maybe

VII. -

VIII. No

IX. No

X. Yes

ALGUNOS RESULTADOS DEL TRABAJO EXPERIMENTAL SOBRE CACAO EN LA ESTACION EXPERIMENTAL AGRICOLA DE TINGO MARIA

J. A. Burgos L. *

Estación Experimental de Tingo María, Perú

INTRODUCCION

En el Perú existen condiciones apropiadas para el cultivo del cacao, pues, de una parte, se halla su territorio comprendido entre las latitudes apropiadas para el cultivo 0° y 20° L.S., y de otra, existe una vasta región dentro de dichos límites en la que existen condiciones de clima apropiados para su cultivo como lo prueban las áreas cacaoteras de Jaén y La Convención.

En el Perú habrían unas 15,000 Hdas. de Cacao, estando la mayor parte de dicha superficie comprendida en las regiones señaladas. Las condiciones del cultivo son en general deficientes, de modo que existe amplio campo para su mejoramiento. Los rendimientos son muy variables de finca á finca en cada región, fluctuando entre 200 y 600 kilogramos por hectárea.

El consumo de cacao en el país es superior a la producción, motivo por el que debe importarse, en gran parte del Ecuador. En 1951 se invirtieron unos siete millones de soles en la importación de cacao crudo y de sus derivados, más en este último renglón.

Podría decirse entonces que el problema de la producción económica de cacao en la región oriental peruana depende ante todo del concurso favorable de factores relativos a vías de transporte, mano de obra y mercados. Regiones como las de Tingo María, Satipo y Pucallpa donde las carreteras han llegado relativamente hace poco presentan condiciones favorables en dicho sentido.

El interés por el cultivo se está intensificando últimamente a raíz de la elevación de precios del producto derivada de la escasez mundial del mismo.

Por consiguiente, existen oportunidades tanto para el desarollo de la industria como para el trabajo de investigación por las

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estaciones experimentales agrícolas.

Se podría preguntar entonces cuáles son los problemas que la experimentación debe resolver en este caso? Posiblemente son, circunscribiendo, los relativos a Introducción de material mejorado del extranjero, la selección y propagación partiendo de las poblaciones de cacao actualmente existente en el país, el estudio de los métodos de cultivo y de control de pestes y, finalmente, los de beneficio.

Considerando el problema desde el punto de vista del fomento del cultivo, se ha de pensar más bien que los aspectos relativos a Extensión y Propaganda y posiblemente a Mercados presentan mayor interés que el de experimentación en las actuales circunstancias pues de lo que se trata es de producir cacao en la mayor cantidad y lo más rápido posible. La ayuda crediticia también puede constituir un factor poderoso para el incremento del área cacaotera nacional.

Sinembargo, es importante que la investigación marche paralela al fomento del cultivo con el objeto de buscar los medios de mejorarlo en lo posible.

INTRODUCCION DE MATERIAL CLONAL MEJORADO

Los primeros trabajos sobre cacao de la Estación Experimental se iniciaron con la introducción de los llamados clones Pound, de la colección existente en terrenos del Ministerio de Agricultura en Iquitos, selección que hizo el Dr. F. J. Pound, ya desaparecido, mientras trabajaba en el Departamento de Agricultura de Trinidad y Tobago.

Actualmente existen unos 40 árboles de los clones Pound #s. 7, 12 y 16, que iniciaron su producción a fines de 1951.

A comienzos de 1953 se hizo una introducción de los clones ICS y SCA de Trinidad y a mediados del mismo año dos introducciones de la Estación Experimental Agrícola del Ecuador.

Actualmente cuenta la Estación Experimental con el siguiente material clonal en estado de trasplante:

Material clonal extranjero en la EEATM.

Procedencia	Clones	Número
Trinidad	ICS - 1	3
	ICS - 6	1

Procedencia	Clones	Número
Trinidad	ICS - 45	3
	SCA - 6	5
	SCA - 12	1
Ecuador	UF - 613	2
	UF - 650	1
	SCA - 6	2
	San Javier - 6 . . .	2
	San Javier - 11 . .	5
	Porvenir - 24 . . .	4
	SCA - 9	1
	ICS - 95	1
	UF - 2	4
	ICS - 48	4
	ICS - 40	2
	SCA - 19	1
Costa Rica	UF - 613	14 (semilla)

Además existen 78 plantas Pound de clones que faltaban en la colección respectiva en la Estación Experimental. El número de clones de la colección, que se compone de 32, como se sabe, es ahora de 15.

En esta forma se contará con un jardín clonal en el que se observará el comportamiento de los clones en cuestión para propagar los que se destaquen y asi mismo para utilizarlos en cruces con los Pound, dado que este es un material resistente a la Escoba de Bruja. También se considera la introducción de material de buenas características de otras regiones del País y en especial de Jaén y La Convención. Asi, últimamente se ha obtenido semilla de árboles con alta proporción de Criollo, de Jaén.

PROPAGACION DEL CACAO EN LA ESTACION

Los almácigos se hacían en camas levantadas sobre el suelo en las que se llegaba a injertar las plantas. El crecimiento era rápido pero las pérdidas elevadas en el transplante final, aún haciéndolo con tierra adherida a las raíces. Por este motivo se está recurriendo al uso de macetas, las cuales son de dos tipos: unas, para los almácigos, constituidas por las vainas de *Dendrocalamus asper*, las que se cortan en porciones de unos 10-15 cm de altura y 6 cm de diámetro y se amarran con cáñamo de la india y otras, hechas con las cañas partidas en listones de 30 cm de largo

y 2-4 cm de ancho las que se amarran con cáñamo, se llenan con tierra apisonando un poco al comienzo y luego se rodean de dos amarras de alambre cerca de los extremos para darles más solidez. (Ver fotos Nos. 7, 8, y 12).

Es necesario regar las macetas en la época de sequía debido a que tienden a secarse con cierta rapidez. Ha dado buen resultado el poner un poco de resíduos descompuestos de racimos de palmera aceitera africana como mulch en las macetas.

En la propagación por injerto se usa semilla de árboles de la localidad escogiendo los que presentan poco ataque por la Escoba de Bruja y que además son productivos. Se injertan, en las macetas, cuando han alcanzado más o menos 60 cm de altura. El método de injerto es el de parche rectangular con el que se obtiene fácilmente un 70% de éxito, como promedio.

Este método ha dado mejores resultados que el de T invertida.

La planta injertada se halla en estado de transplante entre un año y año y medio.

Desde hace un año, más o menos, se ha iniciado en la Estación el método de propagación por estacas. Para tal efecto cuenta ésta con dos propagadores, uno de ellos del tipo Standard de Trinidad y el otro, consistente en una modificación de éste, basada en el propagador Fiester y en el que se deja un nivel de agua constante, más o menos á 30 cm de fondo. El medio de enraizamiento se sostiene, por el fondo, por una malla de tela metálica de 1 cm de diámetro clavada en un marco de madera dura, alquitranada, sostenido por piés cortos de madera también dura y tratada, siendo la altura de éstos, vale decir del fondo de unos 35 cm de altura, mientras que las paredes que sostienen el aserrín de madera, que constituye el medio de enraizamiento, están formadas por planchas de "Eternit" de $\frac{1}{2}$ cm de espesor y de 20 cm de ancho colocadas de modo tal que dejan un espacio libre de 2.5 cm más o menos al contorno de las paredes del propagador.

En la otra mitad, el aserrín de madera está sostenido sobre una plancha de Eternit, de 1 cm de espesor perforado cada 10 cm con espacios de 1.25 cm y colocada sobre el banco de madera a la altura indicada.

El objeto de esto es tratar de saber cuáles son los materiales más apropiados en cuanto a duración se refiere.

Las divisiones interiores se hacen también de planchas de Eter-

nit de ½ cm haciéndolas deslizar en ranuras de cemento construídas en rebordes de las paredes.

En la parte más alta del propagador se dispone una canaleta de cemento cuyo fondo esta un poco más alto que el nivel de los marcos de madera que llevan la tela (arpillera) por humedecer, de modo que el agua baja en parte por gravedad. Los marcos encajan en un reborde de cemento, a una altura un poco más alta que ellos, de manera que el cierre tiende a ser mejor.

En cuanto al propagador Trinidad está construído en la forma conocida y en el se utilizan cubiertas de vidrio.

Ultimamente se ha construido un propagador del tipo Turrialba - 3, con ligeras modificaciones.

La aclimatación se hace en los mismos propagadores.

En un primer ensayo se obtuvo un promedio de 34.4% de 17.1% en el enraizamiento de estacas de rama y de hoja, respectivamente. Después se efectuó el siguiente experimento, con el objeto de observar influencia de las condiciones del medio de enraizamiento:

Tratamientos

1) Testigo sin abonamiento y sin aplicación de agua hirviente.
2) Guano de islas, 200 gr. por compartimento.
3) Aplicación de agua en ebullición al aserrín, empapándolo con la misma.
4) Guano más agua caliente, aplicada en la forma señalada.

Los tratamientos se repitieron 3 veces en cada uno de los dos propagadores primeramente señalados más arriba.

Se usó el clon Pound # 7 para el experimento, la mitad del cual se dispuso como estacas de hoja, y como estacas de rama la otra.

Las estacas fueron tratadas con ácido indolbutírico al 0.8%, las de rama, y al 0.4% las de hoja.

A los 30 dias se comenzaron a levantar las tapas, una pulgada cada día, hasta el 7° en que se quitaron por completo. Las estacas se transplantaron una semana después, en macetas de bambú.

Además del número de estacas se hizo el cómputo del número de raíces principales y se determinó su longitud promedio.

Los resultados obtenidos se expresan en el cuadro siguiente en el que A y B representan el propagador Trinidad y el Modificado, respectivamente:

Tratamiento	Estaca	% de estacas enraizadas A	B
Testigo	Hoja	16.6	5.0
	Rama	33.3	8.3
Guano	Hoja	10.0	14.0
	Rama	37.7	29.3
Guano más Agua caliente . .	Hoja	21.0	5.7
	Rama	25.3	8.3
Agua caliente	Hoja	3.3	---
	Rama	50.0	38.0

El análisis de la varianza, a base del porcentaje de estacas enraízadas, arrojó el resultado siguiente:

Fuente de variación	S.E.	G.L.	C.M.	F.
Total de parcelas	15,973.32	47	-	-
Métodos de riego (M)	760.02	1	760.02	2,110
Repeticiones en (M)	1,193.36	4	298.34	-
Tratamientos (T)	1,417.02	3	472.34	1,311
Estacas (E)	6,030.02	1	6,030.02	16,745 °°
(M) x (T)	353.86	3	117.95	-
(M) x (E)	690.15	1	690.15	1,916
(T) x (E)	1,730.69	3	576.89	1,602
(M) x (T) x (E)	7,789.92	3	929.97	2,582
Error	1,008.28	28	360.10	-

Diferencia en el límite de significación entre promedio de clases de estacas: 5478, para 99% de probabilidades.

Se observa que solo en clases de estacas se obtiene una diferencia significativa.

El análisis de la variancia del N° de raíces en las estacas enraizadas no arroja diferencia significativa.

El análisis de la covariancia entre el porcentaje de estacas

enraizadas y el número de raíces, no arroja diferencias significativas, a pesar de que el coeficiente de correlación del error hallado: r = 0.436, es significativo.

La temperatura en los propagadores varía según los compartimentos, siendo mayor en las orientados hacia el E, y menos en los de posición opuesta. En el primer caso es de 26°C á 26°5C y de 24°5 á 25°C en el segundo. Alrededor de las 3 p.m. hora en que se registran las temperaturas más elevadas, estas no pasan de 32°C.

Un higrotermógrafo colocado en uno de los compartimentos muestra que la temperatura oscila periódicamente cada día, alcanzando su máximo alrededor de 1 á 2 p.m. con cerca de 32° en el propagador modificado y de 31° en el Trinidad. La humedad relativa se mantiene entre 96 y 98% en éste, mientras que en el modificado puede bajar hasta 80% en pocos casos, pero habiendo siempre mayor oscilación que en el primero. Los menores porcentajes de humedad relativa se observan en las horas de mayor temperatura. Parece que los propagadores con tapa de tela requieren un tejido un poco más tupido. Se va a ensayar el llamado "tocuyo".

COMPORTAMIENTO DE LOS CLONES POUND

Un total de 47 árboles de 4½ años de edad, pertenecientes a los clones Pound números: 7, 12 y 16, se halla en el segundo año de registro individual de producción y de resistencia a la Escoba de Bruja.

En el cuadro N°1 se muestran cifras de rendimiento de algunos de los árboles Pound en observación, y asimismo de los promedios hallados hasta ahora en algunos caracteres de las mazorcas respectivas. Para hallar dichos promedios, asi como para calcular algunas constantes estadísticas, que se dan más adelante se ha partido de 20 mazorcas de cada árbol, habiendo medido el largo, diámetro y espesor de las mazorcas y el peso de las mismas y de las almendras, con 0.001 m y 0.1 gr de precisión, respectivamente.

En los gráficos siguientes se muestran las frecuencias observadas en relación con el peso de la mazorca, dimensiones, número y peso de almendras, mientras que el cuadro N°2 muestra la variabilidad de los caracteres estudiados en las mazorcas y almendras en términos de la desviación standard y el coeficiente de variación. Se puede observar que dicha variabilidad es bastante grande en los árboles, especialmente tratándose del peso promedio de las mazorcas y del peso promedio de almendras por mazorca. Es interesante observar esta amplia variabilidad en los caracteres observados en el material Pound, lo cual podría deberse a variaciones provenientes de las condiciones de fertilidad del suelo de la acción del portainjerto ó a los relativos a las condiciones de productividad.

El número de mazorcas de la muestra, sinembargo, está bajo la cifra mínima que recomienda Pound° para estudios de este orden, por lo que podría reducirse un tanto al considerar, mayor número en aquella. Asimismo, cuando los árboles hayan entrado en plena producción.

El ataque de la Escoba de Bruja, Marasmius perniciosus, en los árboles respectivos, continúa en cambio sin manifestarse, lo cual prueba la resistencia de dicho material a tan grave enfermedad. La selección inicial de aquel se hizo en vista de dicha resistencia, como se sabe. Dado que las condiciones de productividad no son en general muy satisfactorias en los clones Pound, su cruce con material de alta proporción de Criollo parece ser de interés. Con tal objeto se ha introducido últimamente a la Estación material de dichas características procedente de Jaén, en la zona cacaotera del norte del Perú.

CUADRO N°1

Rendimiento de clones Pound y promedio de peso, dimensiones y número de almendras en las mazorcas.

Arbol N°	Producción de Mayo 1953 - Abril 1954		Promedios en mazorcas						
	N° de mazorcas	Peso de cacao seco	Peso	Largo	Diámet.	Espesor	Almendras N°	Almendras Peso	una almendra.
		gr.	gr.	cm.	cm.	cm.		gr.	gr.
30- 1	51	728	585	16.7	9.5	1.3	25	91.0	1.5
30- 7	32	1024	579	18.4	8.9	1.1	42	127.6	1.2
30-10	25	1090	593	17.2	8.4	1.1	36	136.8	1.5
30-11	47	1054	636	18.0	8.9	1.2	34	131.8	1.6
31- 3	20	682	620	16.3	9.7	1.3	25	90.7	1.4
31- 7	18	597	597	16.5	8.9	1.4	25	72.7	1.2
31-11	24	736	583	18.4	9.3	1.2	31	92.0	1.2
31-13	20	674	566	16.7	8.7	1.3	37	83.5	1.0
31-16	20	500	564	16.4	8.6	1.3	20	63.5	1.2
31-18	23	551	646	16.1	9.0	1.4	21	68.9	1.3
31-19	47	669	607	17.2	8.8	1.2	25	83.7	1.2
31-20	46	622	266	13.1	6.5	0.7	23	77.8	1.4
31-21	31	823	420	16.6	7.4	0.9	31	43.2	1.3
31-24	25	712	537	16.9	8.3	1.2	29	89.0	1.2
32-12	18	832	476	15.7	7.7	1.2	32	104.0	1.3
32-23	58	666	582	16.8	8.6	1.3	27	83.3	1.3
33- 1	21	231	264	14.5	8.4	1.5	16	28.9	0.7

° J. F. Pound, The Genetic Constitution of the Cacao Crop, 1 and 2 Reports on Cacao Research, 1931, 1932. The Imperial College of Tropical Agriculture, St. Agustine, Trinidad.

En cuanto al ataque de insectos, se ha observado al de hormigas "coqui" Atta sp., especialmente en las plantas de 1 á 2 años. Su combate se hace eficazmente con Aldrin al 2.5%, en tiza, aplicado en polvo en los orificios de los nidos.

En el follaje, y en la época de sequía, se ha observado el ataque bastante intenso de insectos defoliadores, aparente debido a Macrodactylus sp., habiéndose controlado eficazmente con espersiones de DDT al 0.5% en agua, cada 30 dias más o menos. El efecto sobre los insectos polinizadores no ha sido mayor, pues la fructificación ha sido normal. En la cara inferior de las hojas aparece con cierta intensidad el ataque de quereza blanca pequeña, Coccidae, cuyo control está en estudio.

ENSAYOS DE ABONAMIENTO Y DE APLICACION DE ELEMENTOS MENORES

En un ensayo preliminar de dicha naturaleza, consistente en la aplicación de dos dosis diferentes de N, en la forma de sulfato de Amonio (1/3) y de guano de islas de 12% de N total (2/3) y a razón de 180 gr. de N y 360 gr. de N por árbol, se obtuvieron resultados expresados en número de mazorcas por árbol, casi iguales en el testigo, sin abono y la dosis más alta, mientras que fué un poco mayor del doble para la dosis menor. El ensayo se hizo en árboles de tres clones Pound, diferentes, con 5 réplicas por tratamiento. Esto demuestra las posibilidades del uso de guano de islas, las que se investigarán con más detalle.

También se está ensayando la aplicación de elementos menores para tratar de corregir ciertos síntomas anormales en las hojas, consistentes en su deformación y en la aparición de zonas verdes alrededor del tejido de color amarillo. Según el Dr. Paul de Tarso Alvim, que visitó la Estación hace algún tiempo, se trataría de una deficiencia de Boro. Se está tratando de aplicar este elemento asi como Cu, Mu, Mg y Zn, en forma de inyección y partiendo de los Versenatos de estos últimos a la concentración de 1% de la sal. La absorción es generalmente muy lenta, aunque en el caso del Cu, dió lugar a la caída total de las hojas en la rama respectiva.

El método de inyección intervenal de Roach resultó eficaz solamente para diagnosticar la deficiencia de N, usando para ello una solución de urea al 1%.

ESPECIES FORESTALES PARA PROVEER SOMBRA AL CACAO

Se halla en marcha un experimento consistente en una comparación entre cuatro especies forestales de Tingo María con el fin

indicado. Se inició en 1951, y constaba de las especies siguientes, repetidas 4 veces: "Oropel", Erythrina sp., "Pacae", Inga sp., "Pashaco", Schizolobium sp., "Mataratón", Gliricidia sepium, y Testigo, sin sombra.

El terreno es areno-limoso, poco profundo, habiendo sido previamente cultivado.

En vista de haber sido insatisfactorio el comportamiento del Mataratón, lo cual se ha observado por lo demás en otros puntos de la Estación, se descartó del experimento dejando solo las tres restantes.

La parcela experimental se compone ahora de 7 árboles, rodeada de dos líneas de contorno. El distanciamiento es de 5 m x 5 m en tresbolillo. Se emplea el clón Pound N° 12, solamente.

El Pashaco es bastante rústico, pero tiene el inconveniente de su crecimiento poco ramificado, que se va tratar de conseguir por medio de la poda. El Pacae, parece ser hasta ahora la especie de mejor comportamiento.

En este experimento se dispondrá uno de abonamiento más tarde.

ENSAYOS DE FERMENTACION

Dadas las cantidades relativamente pequeñas, de almendras disponibles actualmente, se está haciendo uso de un fermentador del tipo llamado "solar", originado en Trinidad para los ensayos en cuestión. Se han logrado fermentar cantidades hasta de un kilogramo de almendras frescas, con buen resultado. También se ha ensayado el método químico de beneficio.

El cuadro a continuación muestra algunos resultados de estos ensayos:

Variaciones de peso en el beneficio del cacao Pound en la EEATM.

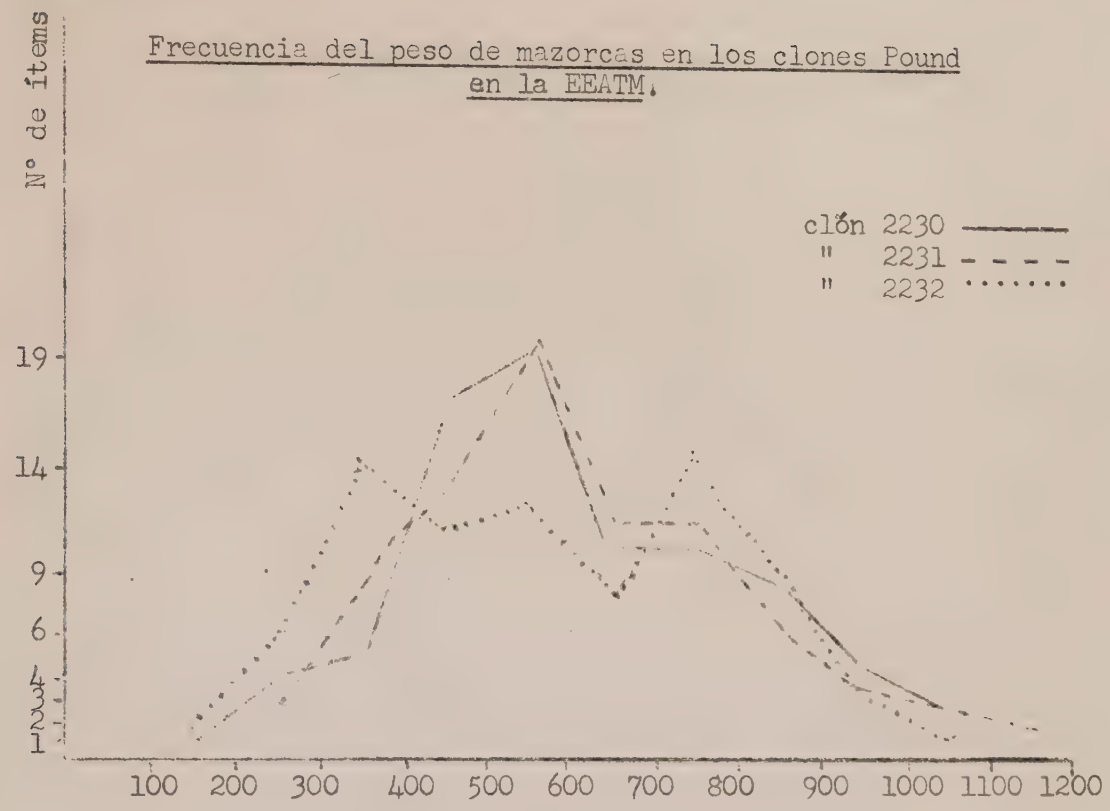
Muestra	Peso inicial	Pérdida de peso en la:			
		Fermentación	Lavado	Secado	Total
#	Kgr.	%	%	%	%
1	3.540	-	-	-	77.7
2	1.340	59.7	17.5	49.3	75.8
3	1.290	40.8	11.1	41.2	73.0
4°	1.051	-	29.3	-	72.8

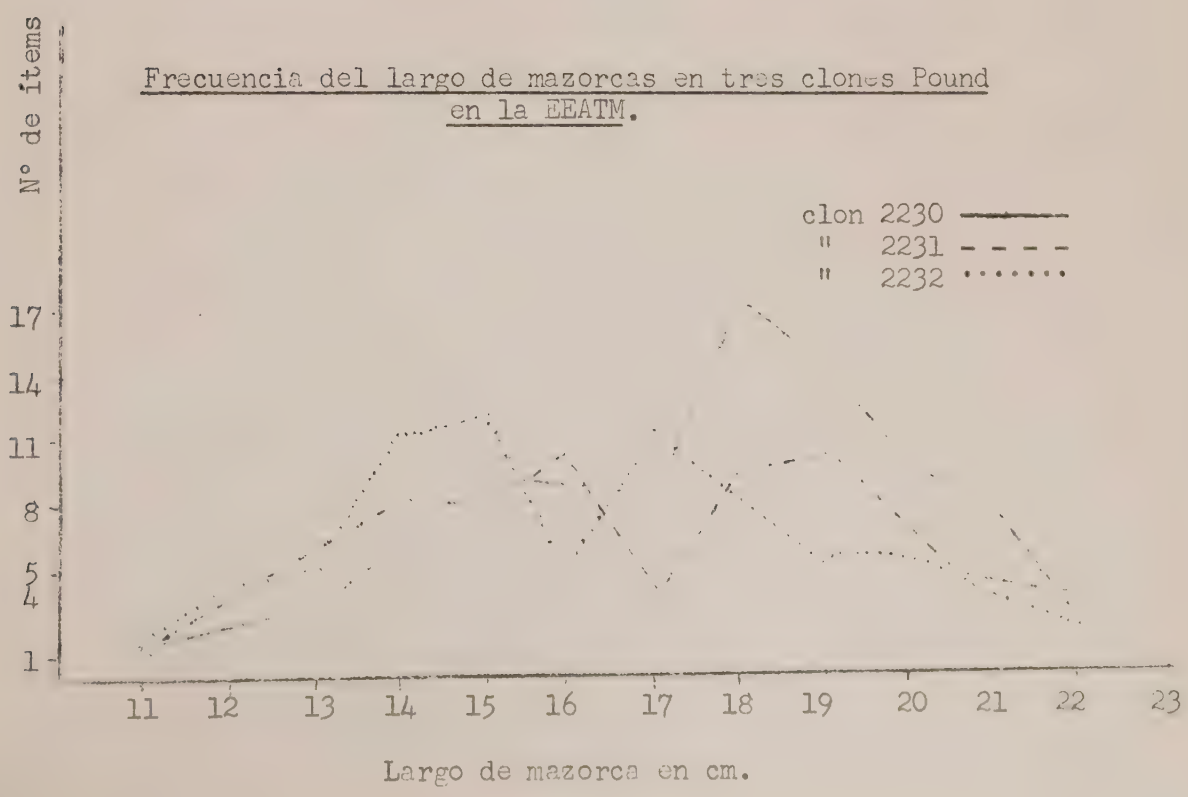
° Esta muestra se trató por el método químico, usando una solución de NaOH al 6% por 2 horas, lavando con agua corriente y secando al sol.

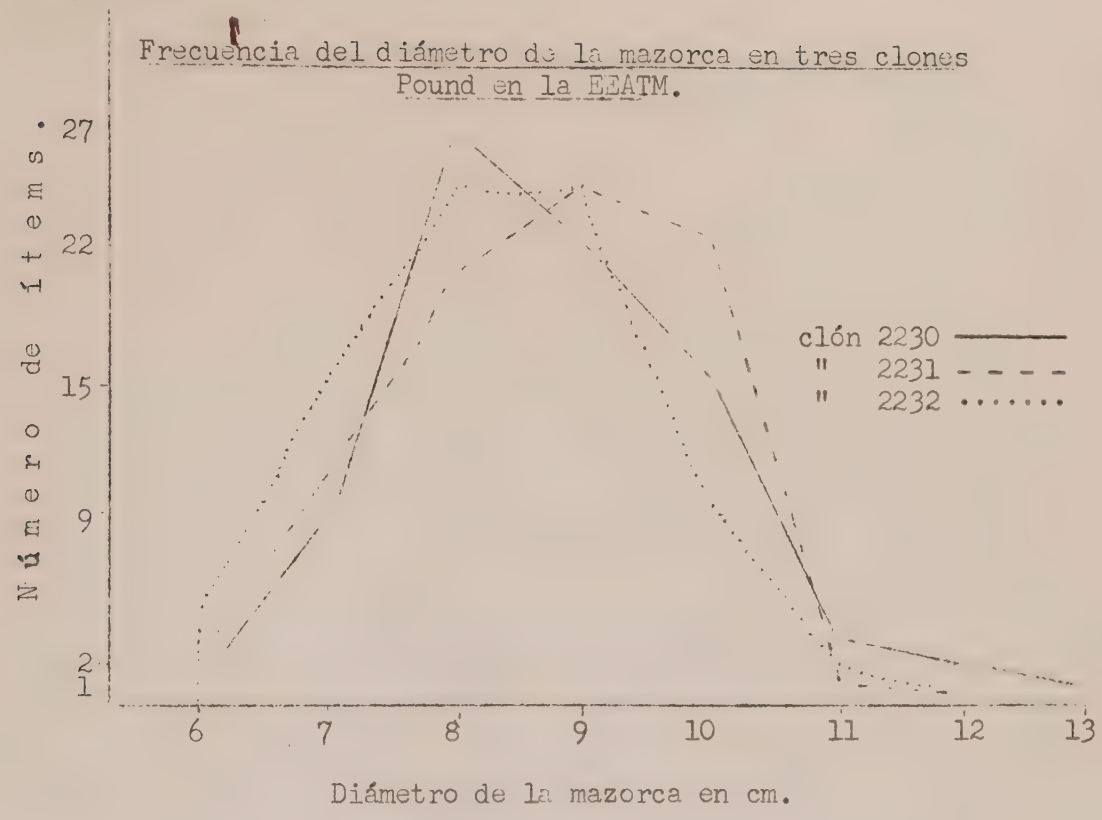
Las almendras fermentadas por el método corriente son más uniformes en coloración y tienen mejor aroma que las del método químico que produce también almendras más oscuras.

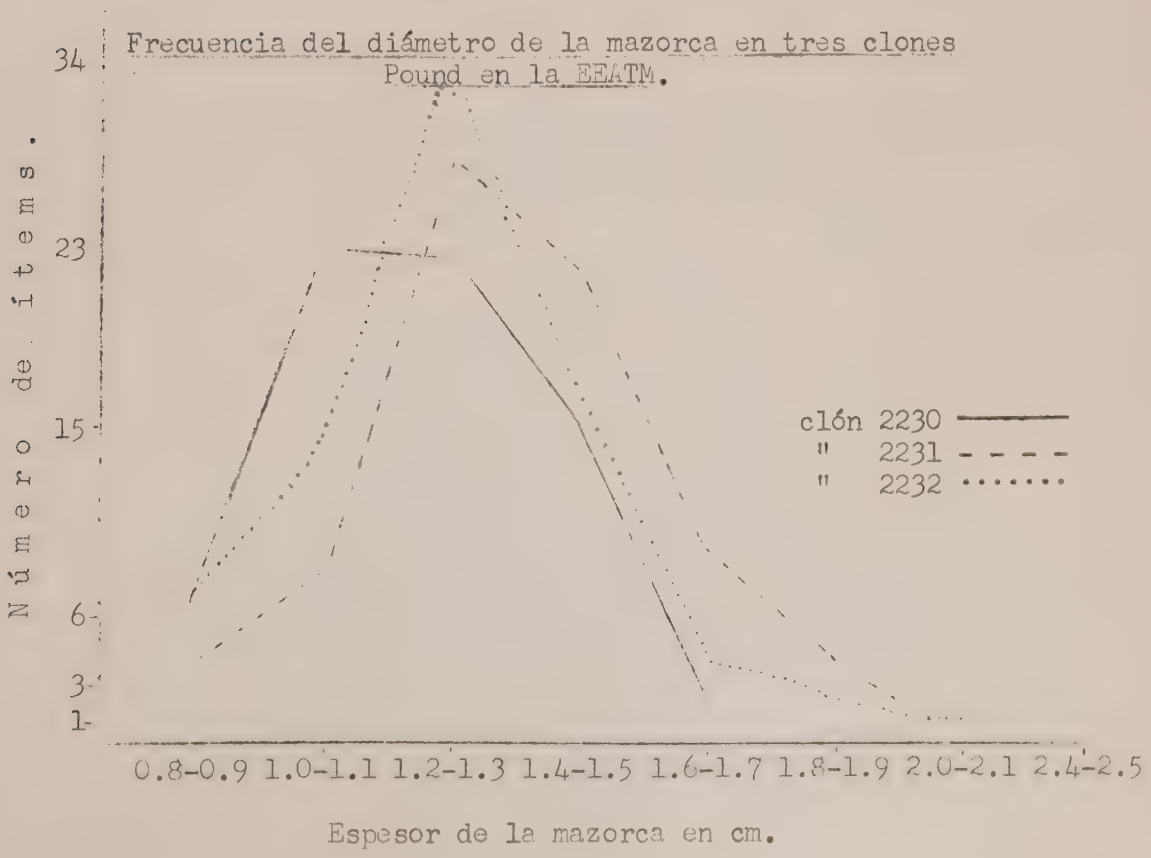
NUEVOS EXPERIMENTOS

Dado que el trabajo experimental prácticamente se inicia en el país, lo cual significa que se desconocen una serie de problemas técnicos cuya solución puede ser de aplicación más o menos rápida por los agricultores, es que se han planeado algunos nuevos experimentos de carácter crítico que se iniciarán en el curso del presente año y cuyos títulos son los siguientes: Experimento N° 10-3-3: "Comparativo de distanciamiento, sombra, y mulching en plantaciones de cacao" y el 10-3-4: "Métodos de establecimiento de plantaciones de cacao partiendo de monte real".

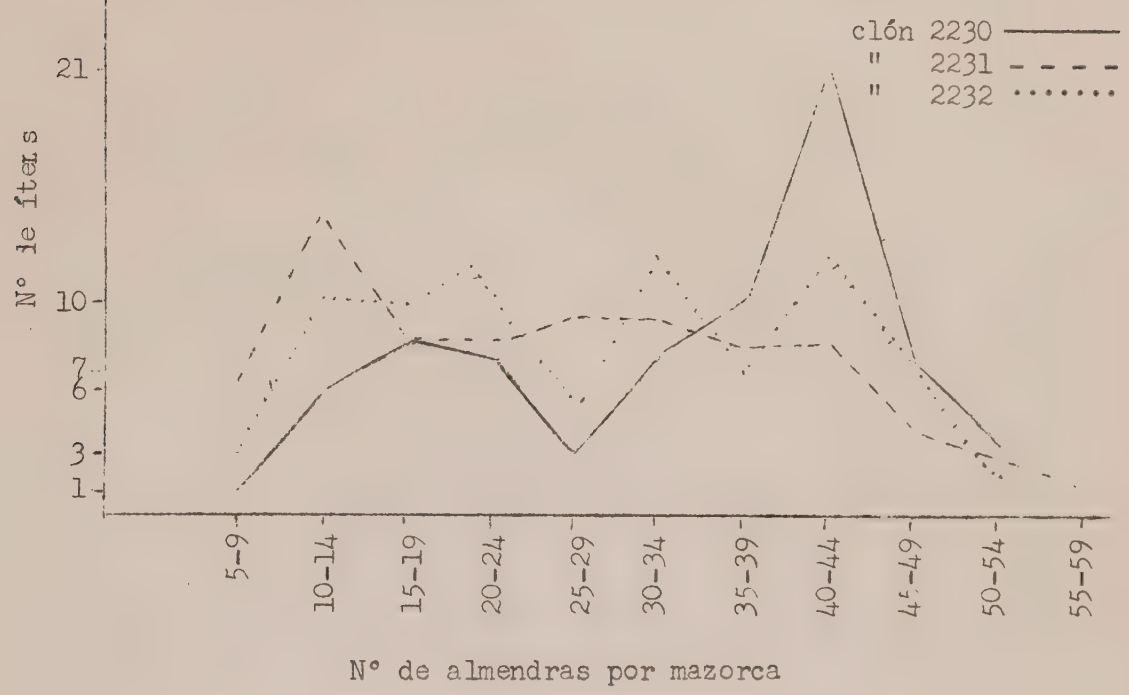

Frecuencia del peso de mazorcas en los clones Pound en la EEATM.
N° de ítems
clón 2230
" 2231
" 2232
19
14
9
6
4
1
100 200 300 400 500 600 700 800 900 1000 1100 1200
Peso de mazorcas, en gramos.


Frecuencia del largo de mazorcas en tres clones Pound en la EEATM.
N° de ítems
clon 2230
" 2231
" 2232
17
14
11
8
5
4
1
11 12 13 14 15 16 17 18 19 20 21 22 23
Largo de mazorca en cm.

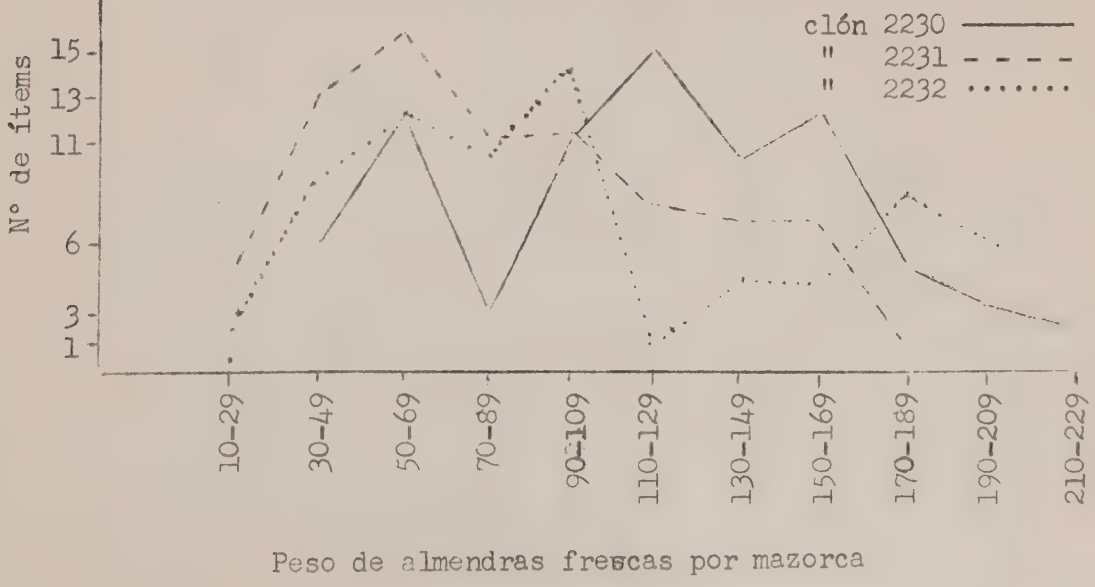

Frecuencia del diámetro de la mazorca en tres clones
Pound en la EEATM.
Número de ítems.
27
22
15
9
2
1
6
7
8
9
10
11
12
13
clón 2230
" 2231
" 2232
Diámetro de la mazorca en cm.


Frecuencia del diámetro de la mazorca en tres clones
Pound en la EEATM.
Número de ítems.
34
23
15
6
3
1
0.8-0.9
1.0-1.1
1.2-1.3
1.4-1.5
1.6-1.7
1.8-1.9
2.0-2.1
2.4-2.5
clón 2230
" 2231
" 2232
Espesor de la mazorca en cm.

Frecuencia del N° de almendras por mazorca en tres clones Pound en la EEATM.



Frecuencia del peso de almendras frescas por mazorca en tres clones Pound en la EEATM.



CUADRO N° 2

Promedio, desviación standard y coeficiente de variación en las mazorcas de clones Pound en la EEATM.

		30-1	30-7	30-10	30-11	31-3	31-7	31-11	31-13
Peso	Prom.	585 gr.	519 gr.	593 gr.	636 gr.	620 gr.	597 gr.	583 gr.	566 gr.
	D. S.	0.200	0.140	0.227	0.234	0.268	0.188	0.176	0.218
	C. V.	34.21%	24.18%	38.27%	36.47%	43.30%	31.53%	30.23%	38.45%
Largo	Prom.	16.7 cm.	18.4 cm.	17.2 cm.	18.0 cm.	16.3 cm.	16.5 cm.	18.4 cm.	16.7 cm.
	D. S.	2.53	2.23	3.06	2.86	2.98	2.93	2.84	2.86
	C. V.	15.16%	12.12%	17.81%	15.92%	18.25%	17.80%	15.44%	17.15%
Diámetro	Prom.	9.5 cm.	8.9 cm.	8.4 cm.	8.9 cm.	9.7 cm.	8.9 cm.	9.3 cm.	8.7 cm.
	D. S.	1.842	1.280	1.550	1.390	2.445	1.022	0.743	1.331
	C. V.	19.38%	14.38%	18.45%	15.61%	25.20%	11.48%	7.99%	15.29%
Espesor	Prom.	1.3 cm.	1.1 cm.	1.1 cm.	1.2 cm.	1.3 cm.	1.4 cm.	1.2 cm.	1.3 cm.
	D. S.	0.154	0.297	0.261	0.244	0.176	0.297	0.326	0.354
	C. V.	11.49%	27.03%	23.77%	20.32%	13.56%	21.17%	27.17%	27.22%
Número de almendras	Prom.	25	42	36	34	25	25	31	37
	D. S.	11.33	12.00	12.29	12.96	12.87	12.25	13.79	13.36
	C. V.	45.32%	28.56%	34.13%	38.10%	51.47%	49.01%	44.46%	36.09%
Peso de almendras	Prom.	91.0 gr.	127.6 gr.	136.8 gr.	131.8 gr.	90.7 gr.	72.7 gr.	92.0 gr.	83.5 gr.
	D. S.	40.99	11.10	52.03	55.46	49.62	37.46	35.32	42.23
	C. V.	45.04%	8.70%	38.03%	42.07%	54.70%	5.15%	38.60%	50.57%
Peso de una almendra	Prom.	1.5 gr.	1.2 gr.	1.5 gr.	1.6 gr.	1.4 gr.	1.2 gr.	1.2 gr.	1.0 gr.
	D. S.	0.278	0.232	0.336	0.417	0.304	0.478	0.292	0.269
	C. V.	18.54%	19.31%	22.43%	26.08%	21.74%	39.83%	24.34%	26.85%

(Este cuadro continua en la página N°16)

CUADRO N°2

Promedio, desviación estandard y coeficiente de variación en las mazorcas de clones Pound en la EEATM.

31-16	31-18	31-19	31-20	31-21	31-24	32-12	32-23	33-1		
564 gr.	646 gr.	607 gr.	266 gr.	420 gr.	537 gr.	476 gr.	582 gr.	264 gr.	Prom.	Peso
0.200	0.216	0.226	0.100	0.150	0.241	0.181	0.113	0.170	D. S.	
35.41%	33.45%	37.23%	37.72%	35.71%	44.83%	38.02%	29.73%	64.26%	C. V.	
16.4 cm.	16.1 cm.	17.2 cm.	13.1 cm.	16.6 cm.	16.9 cm.	15.7 cm.	16.8 cm.	14.5 cm.	Prom.	Largo
2.66	3.04	3.28	2.86	2.52	3.79	3.02	3.11	3.99	D. S.	
16.23%	18.55%	19.10%	21.84%	15.19%	22.44%	19.21%	18.52%	27.51%	C. V.	
8.6 cm.	9.0 cm.	8.8 cm.	6.5 cm.	7.4 cm.	8.3 cm.	7.7 cm.	8.6 cm.	8.4 cm.	Prom.	Diámetro
0.987	0.989	1.012	0.918	1.031	1.283	1.144	0.722	2.980	D. S.	
11.47%	10.98%	11.50%	14.12%	13.92%	15.45%	14.85%	8.40%	35.46%	C. V.	
1.3 cm.	1.4 cm.	1.2 cm.	0.7 cm.	0.8 cm.	1.2 cm.	1.2 cm.	1.3 cm.	1.5 cm.	Prom.	Espesor
0.231	0.248	0.179	0.179	0.369	0.271	0.251	0.147	0.167	D. S.	
11.74%	17.73%	14.91%	25.60%	40.94%	22.61%	20.95%	11.30%	11.13%	C. V.	
20	21	25	23	31	29	32	27	16	Prom.	Número de almendras
11.75	12.09	12.89	14.78	10.94	14.91	15.40	11.80	11.36	D. S.	
58.75%	57.55%	51.56%	64.26%	35.29%	51.41%	48.12%	43.70%	7.10%	C. V.	
63.5 gr.	68.9 gr.	83.7 gr.	77.8 gr.	43.2 gr.	89.0 gr.	104.0 gr.	83.3 gr.	28.9 gr.	Prom.	Peso de almendras
36.83	43.08	39.31	27.48	37.11	50.22	46.74	31.92	21.46	D. S.	
58.00%	62.52%	46.96%	35.32%	34.39%	56.42%	44.94%	38.31%	74.25%	C. V.	
1.2 gr.	1.3 gr.	1.2 gr.	1.4 gr.	1.3 gr.	1.2 gr.	1.3 gr.	1.3 gr.	0.7 gr.	Prom.	Peso de una almendra
0.403	0.467	0.315	0.226	0.332	0.340	0.317	0.359	0.296	D. S.	
33.60%	35.90%	26.28%	16.15%	25.51%	28.29%	24.41%	27.62%	42.22%	C. V.	

28 june
Cacao 204-
54

COMENTARIOS Y RECOMENDACIONES SOBRE EL CULTIVO DE CACAO EN LAS PROVINCIAS DE JAEN Y BAGUA, PERU *

J. A. Burgos L. **

Estación Experimental de Tingo María, Perú

INTRODUCCION

A raíz de la visita a la Estación Experimental en Tingo María de los ingenieros Watson y J. Campos para observar los trabajos que allí se realizan para aplicarlos en el establecimiento de cacao en gran escala en Bagua, fué acordado el viaje a Jaén y Bagua de los señores Long, Garayar y el que escribe, del personal técnico de dicha Estación, con el objeto de observar el cultivo del cacao en dicha región y recomendar lo conveniente. Mas tarde, sinembargo, la visita en cuestión fué realizada por este último solamente.

El cacao se cultiva desde mucho tiempo atrás, principalmente en el valle de Jaén, ubicado en la provincia del mismo nombre que forma parte del departamento de Cajamarca. En la provincia de Bagua, en el valle de Utcubamba, en cambio, donde se desea plantar el cacao en gran escala, prácticamente no existe actualmente, si se compara con la de Jaén.

La potencialidad productiva de cacao en Jaén puede aumentarse grandemente por la aplicación de medidas culturales relativamente sencillas, que describiremos más adelante y que los mismos finqueros están llamados a poner en práctica. Sinembargo, su acción sería más efectiva de contar con ayuda técnica y financiera de parte del Gobierno como se hace en otros países. En las actuales circunstancias el campo para una labor de Extensión Agrícola bien planeada y conducida, es en tal sentido, completamente oportuna.

Hemos sido portadores, de un memorial firmado por los principales finqueros de cacao en Jaén y Bellavista y dirigido al Señor

* Extracto del trabajo titulado "Informe del viaje oficial a Jaén y Bagua", presentado por el autor a la V Reunión del Comité Técnico Inter-Americano del Cacao. El trabajo original, con sus respectivas ilustraciones se encuentra en la biblioteca del Instituto.

** Ing. Agr. Jefe del Depto. de Arboricultura, Est. Exp. Tingo María, Perú.

Ministro de Agricultura, en el cual se solicita precisamente dichas formas de ayuda.

Los objetivos del viaje a Jaén se pueden concretar en la siguiente forma: 1) observación de las condiciones de cultivo del cacao y de otros cultivos en Jaén y Bagua; 2) selección primaria de árboles de buenas características en algunas fincas de cacao en el valle de Jaén, como base para la utilización inmediata de su semilla y para la observación futura de su comportamiento en vista de la selección de plantas madres para la multiplicación vegetativa y su uso en el mejoramiento y en la extensión de las plantaciones; 3) toma de muestras de mazorcas para el estudio biométrico del cacao y para introducir material con alta proporción de Criollo en Tingo María, y 4) recomendaciones y consejos de diverso orden suministrado a los finqueros de cacao y a quienes desean establecer nuevas plantaciones.

El viaje se hizo por avión, en el recorrido entre ciudades. La visita de las fincas, elegidas más bien al azar, en cada uno de los sectores más importantes tanto en Jaén como Bellavista, se hizo en jeep, a mula y á pié.

En dicha visita el que escribe estuvo asesorado en todo momento por el Ingo. J. Campos conocido agricultor de Jaén, a quien deseamos presentar nuestro agradecimiento por su valiosa ayuda. Igualmente a los ingenieros Watson y A. Gazzo, Gerente y Superintendente respectivamente de la Hda. Valor, R. Guzmán, Jefe de la Oficina del Estanco del Tabaco, en Jaén, R. Carranza, Jefe del Proyecto de Mecanización Agrícola en Bagua, T. Custodio, Superintendente de la Hda. Morerilla, R. Neyra, Administrador de Campo de las Hdas. Sta. Cruz y Pajillas, Ingo. Portugal, Jefe de la Campaña arrocera de Jaén y Bagua y Sr. N. González, Subprefecto de la Provincia, por su cooperación para hacer posibles los objetivos de nuestro viaje é igualmente, a los señores finqueros de Jaén, cuyos nombres se mencionan en este informe, por su solicitud por mostrarnos sus fincas y proveernos del material para el estudio respectivo.

COMENTARIOS Y RECOMENDACIONES

Existe la creencia entre los agricultores deseosos de tecnificar mejor el cultivo del cacao, -a raíz de los altos precios que viene adquiriendo el producto en el mercado mundial- y conocedores de la información suministrada por la Estación Experimental Agrícola en Tingo María en sus publicaciones, que la mejor manera de resolver el problema del establecimiento de plantaciones libres de la amenaza de la "Escoba de Bruja", Marasmius perniciosus, sería la de usar en gran escala el material Pound que posee la Estación,

material seleccionado en vista de su resistencia al ataque de dicha enfermedad, favorable característica que se continúa observando en los nuevos árboles obtenidos por vía vegetativa. Este deseo muy natural por cierto, está confrontado sinembargo por la escasez del material disponible actualmente en la Estación, de una parte, y porque dicho material no es aún bien conocido en sus condiciones de productividad y calidad como para usarlo sin más ni más en el establecimiento de grandes plantaciones de cacao, de otra.

Algunas personas, han creído, incluso, que el problema de establecer plantaciones de alto rendimiento en el país consiste sencillamente en importar el material necesario de esas características, de países donde el cultivo está avanzado. Medida más bien inaconsejable, dado el costo elevado del transporte, el desconocimiento más o menos aparente del cultivo técnico del cacao y el serio peligro de la introducción de pestes que no existen aún en el país. En las plantaciones de cacao existentes en éste se cuenta, en cambio, con un magnífico material para extender el cultivo, en primer lugar y luego para trabajos de selección tendentes a su mejoramiento. De allí que siempre recomendemos el uso de dicho material y de estudiarlo teniendo en mente, a fin de cuentas, la economía del esfuerzo y dinero necesarios para incrementar la producción del cacao en el país. Hemos tenido asi oportunidad de disuadir de proyectos inaparentes para el fin propuesto en las actuales condiciones y de encauzar mejor el esfuerzo por realizar. En cuánto dinero se pueden traducir estos consejos para los agricultores, no lo sabemos, pero puede constituir una demostración de los fines que persigue la Estación Experimental en Tingo María.

Botánicamente las plantaciones de cacao de Jaén pertenecen al tipo Forastero, variedad amelonado, tipo que no es puro en gran número de casos, sinembargo, por exhibir cierta proporción del tipo Criollo, dada la presencia de almendras de color morado claro y blanco en las mazorcas. En menor proporción es posible observar las variedades Calabacillo y Cundeamor de aquel tipo, presentándose también en ellas almendras de color claro y blanco. Como se sabe no existe correlación entre el color de la semilla y la forma del fruto. La procedencia del Criollo en la población de cacao en Jaén no parece ser bien conocida. Es posible que haya habido cierta influencia del Criollo Venezolano, de la variedad "Amarilla", dado que el color de las mazorcas maduras de cacao en Jaén es prácticamente amarillo solamente, introducido de la vecina república del Ecuador, de la región de Esmeraldas, donde, según Van Hall (1) se nota influencia del cacao Venezolano señalado.

La presencia del Criollo confiere especial interés en los trabajos de selección dado que es el tipo que produce el cacao de mejor

calidad conocida. Cruces con los clones Pound son de alto interés, p.e.

El cultivo del cacao en Jaén, visto de un modo general, se caracteriza por lo rutinario y muchas veces deficiente ejecución de las prácticas culturales en las plantaciones antiguas. En algunos casos se nota dedicación para el cultivo y en otros un abandono completo de las plantaciones a su propia suerte. Felizmente, podemos decir que el problema sanitario, especialmente en relación a la Escoba de Bruja, no es serio. En cambio se nota cierta tendencia al incremento de la podredumbre negra, producida por Phytophthora. La plaga de los chinches Monalonium, de otra parte, es de primaria importancia en su control. No observamos síntomas precisos de la existencia de Monilia, en los recorridos efectuados.

Condición muy típica del cultivo del cacao en Jaén reside en la necesidad del riego dado que la precipitación anual es insuficiente para las necesidades del mismo. En este sentido, y comparando con otras regiones donde el cacao, se cultiva bajo lluvia, la de Jaén estaría en desventaja. Esto se aplica con mayor énfasis a las zonas a menor elevación y de más baja precipitación donde se desean establecer nuevas y extensas plantaciones. Ventajas del cultivo bajo riego son las relativas al control de la erosión del suelo y hasta cierto punto de la incidencia de enfermedades fungosas, lo cual explicaría su baja incidencia actual. Asi mismo, el influjo educativo sobre el factor hombre al exigirle mayores cuidados, propendiendo asi a la aplicación del esfuerzo metódico y sostenido como base del éxito de la empresa. Por lo demás, el cacao se cultiva bajo riego en la isla de Guadalupe y en la Costa del Pacífico de Nicaragua, por ejemplo.

Un uso racional del agua es muy conveniente, como se puede suponer.

En cuanto a las recomendaciones que podemos hacer en vista de lo observado son las siguientes:

1) Al establecer nuevas plantaciones de cacao, especialmente en la región de Bagua, estar seguro de contar con una dotación de agua de riego suficiente para atender a las necesidades del cultivo. El cacao requiere por lo menos 1200 mm de lluvia anual, bien distribuídos. Dado que en Jaén caen más o menos 1000 mm al año, ello quiere decir que se debe aplicar la diferencia, 200 mm, equivalentes a 2000 metros cúbicos por hectárea, en forma de riego, distribuyéndolos convenientemente en los meses de sequía intensa, preferentemente. En Bagua, con unos 400 mm anuales de precipitación se ha de requerir el equivalente de 800 mm de precipitación,

ó sean 8000 metros cúbicos por hectárea, para aplicarlos como riego en la forma indicada. Es conveniente que el suelo esté permanentemente húmedo, aunque no anegado, en el curso del año y no que reciba riegos fuertes con intérvalos largos en los que llegue a secarse casi por completo. El cacao requiere humedad constante en el suelo y sufre mucho con la sequía.

2) Usar la semilla de árboles vigorosos, con pocas ó ninguna escoba y con almendras del color más claro posible, para establecer las nuevas plantaciones. Es conveniente que cada agricultor observe los árboles de su finca con el objeto de escoger los que reúnan las características indicadas. Si la producción de estos árboles es alta y no varía ó varía poco en uno ó dos años -lo cual requiere simplemente contar el número anual de mazorcas y pesar las almendras- entonces se podrá usar con mayor garantía para establecer nuevas plantaciones y mejor aún para su propagación por vía vegetativa, por estacas ó por injerto, por ejemplo. En las fincas donde se han marcado árboles es muy importante registrar la producción anual de cada uno de ellos como se ha dicho y suministrar los datos repectivos a la persona encargada de remitirlos a la Estación Experimental Agrícola en Tingo María para su evaluación.

Usar la semilla seleccionada para reemplazar los árboles poco productivos de la plantación, sembrándola ó trasplantando al pié de los mismos y cortando el árbol indeseable cuando la nueva cosecha se inicia. Esta sustitución se puede hacer mejor con plantas obtenidas por vía vegetativa, pero mientras ésto no suceda se puede hacer con semilla. El agricultor debe tratar siempre de aumentar los rendimientos de cacao seco por hectárea de su finca, pues ello le representará mayores ingresos.

3) El sombrío se puede hacer por vía directa en aquellos sitios donde es posible inundar el terreno al regarlo, como una forma de destruir las hormigas; en caso contrario, es conveniente preparar almácigos y viveros usando para esto último algún material abundante en la región, como tallos de plátano seco p.e., para confeccionar los recipientes.

Con plantas bien arraigadas, de un año de edad, el control de las hormigas puede ser más fácil, una vez en el campo. Asimismo, las "limpias", pueden ser menos frecuentes y menos costosas.

4) La práctica consistente en sembrar yuca y plátano un año antes del cacao es conveniente. Si no se desea plantar yuca se la puede sustituir ventajosamente con frijol de palo. Es muy recomendable plantar, en el primer año también, árboles de "Pacae",

Inga sp., á 15 m x 15 m, con el objeto de proveer de sombra permanente. Estos árboles enriquecen el suelo con sus raíces y hojas, si se desea se puede plantar á 7.50 m x 7.50 m para ralear más tarde á 15 m. La sombra ligera conserva mejor el cacaotal en climas secos, pues tiende a reducir el consumo de nitrógeno. Las ramas de los árboles de sombra no deben estar a menos de un metro sobre las copas del cacao. Podar si es necesario.

5) En terrenos de pendiente fuerte, mayor del 10% regar de preferencia siguiendo las curvas del nivel del terreno para las acequias conductoras y en sentido perpendicular ó inclinado para las regaderas, con una separación de 4 - 5 metros entre ellas. Se debe evitar que el agua de riego corra demasiado rápido por el terreno, pues esto provoca la pérdida de suelo por arrastre y la baja progresiva de los rendimientos sin que ello se explique fácilmente.

En terrenos de poca pendiente se podría regar en amelgas, p.e., de 15-20 m de ancho, con regaderas paralelas a la principal y dispuestas en sentido perpendicular a la pendiente. En la parte inferior de cada amelga disponer desagües paralelos. Se podría usar la hojarasca para levantar los bordes, que no es necesario que sean muy altos.

Se debe aplicar los riegos por lo menos una vez por mes en las plantaciones adultas y con más frecuencia en las jóvenes.

6) La limpieza de las plantaciones es fundamental. Es conveniente cortar y extraer fuera del terreno ó quemar, toda madera seca de los árboles, pues constituye un medio muy apropiado para la perpetuación é intensificación de las plagas de insectos y hongos. Destrúyanse los nidos de hormigas en los árboles para lo cual se puede empapar un trapo en kerosene ó petróleo colocado en el extremo de una caña de largo apropiado para aplicarlo a los nidos tratando de mojarlos bien. Usese serrucho para cortar las ramas secas y para la poda. Los serruchos curvos y las tijeras de poda son muy apropiados para esto último. Cuando las heridas de poda sean grandes aplíquese alquitrán vegetal con una brocha ó bien pasta bordalesa, que se puede obtener en la Granja Agropecuaria. Limpiar frecuentemente el tronco de los árboles de musgos y liquenes. Evitar la poda excesiva pues tiende a reducir la producción. Cortar las ramas débiles ó enfermas y las que se entrecruzan con las principales, solamente.

7) Si se desea abonar las plantaciones consultar primero a los agentes agrícolas del gobierno quienes darán directivas apropiadas para el mejor uso del abono. Los árboles adultos se pueden

abonar con 1 Kgr. de guano de islas por árbol al año. Aplicar el abono haciendo una zanja circular á 1 m del tronco de unos 10 cm de profundidad, regar el guano uniformemente y tapar con la tierra de la zanja. También se puede aplicar sulfato de amonio y sulfato ó cloruro de potasa a las dosis de 500 gramos y 100 gramos por árbol al año, aplicados en la misma forma. Se pueden aplicar el guano ó las sales, después de la cosecha principal ó bien en dos partes, una después de la cosecha y otra a los 6 meses. En esta última forma se puede aprovechar mejor el abono.

Plantar alguna cobertura para el suelo en los primeros años de vida del cacaotal. Solicitar semilla de Indigófera endecaphylla ó de Kudzu tropical de los servicios oficiales y sembrarla entre las líneas una vez cosechados los cultivos anuales. Será necesario regar estas coberturas. Esto permite conservar el suelo y reducir los gastos en limpiezas.

8) Una práctica que no se debe olvidar es la de hacer la cosecha con alguna herramienta de corte apropiado como machete ó mejor con cuchillos curvos de poda con las que se debe seccionar netamente el pedúnculo que sostiene el fruto sin herir la prominencia ó "cojín" de donde sale. La cosecha arrancando la mazorca es funesta para la producción y para la vida del árbol. Al arrancar los frutos el cojín se malogra pudiendo no volver a producir mazorcas, lo que dá por resultado que éstas se formen en las ramas altas dificultando y encareciendo la cosecha.

9) Se pueden reducir los efectos de la escoba de bruja cogiendo sistemáticamente las escobas y dejándolas en el suelo simplemente. Para que esta labor sea verdaderamente efectiva la deben hacer cada uno de los finqueros.

Ralear las plantaciones demasiado densas para favorecer la aeración. Evitar la plantación de muchos árboles frutales ó de café en el cacaotal puesto que esto favorece los ataques de la escoba de bruja.

10) Las medidas indicadas favorecerán también el control del "lunarejo" ó "hielo" producida por el hongo Phytophthora. Para el control directo solicitar la ayuda del agente agrícola ó de la campaña encargada del control. Este se hará con caldo bordalés de la fórmula 4-4-50 (1%) y se aplicará con bombas de presión para cubrir completamente el follaje. Con la ayuda del agente agrícola para dar las directivas necesarias, los finqueros se pueden unir para comprar las bombas de aplicación de tamaño conveniente. Hay que hacer las aplicaciones cada 30 dias, por ejemplo.

11) Para el control del chinche Monalonium que daña los frutos con sus picaduras se pueden hacer aplicaciones de sulfato de nicotina al 0.2%, ó de emulsión de jabón y kerosene.

12) Tratar de formar cooperativas de producción y de venta de las cosechas.

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